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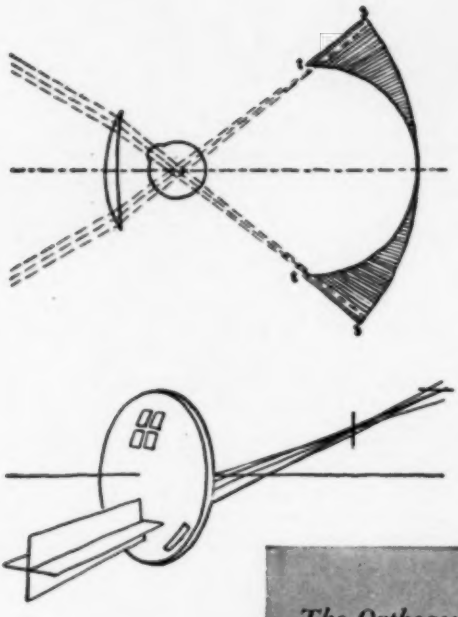

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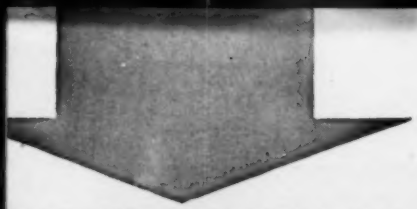

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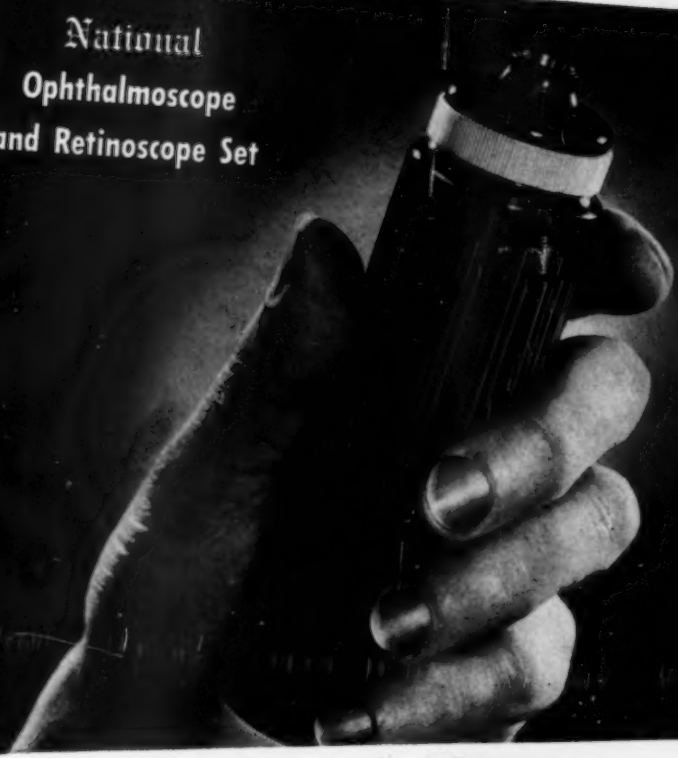

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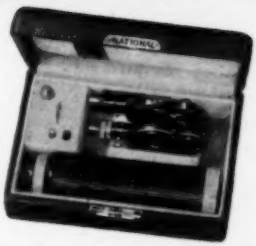

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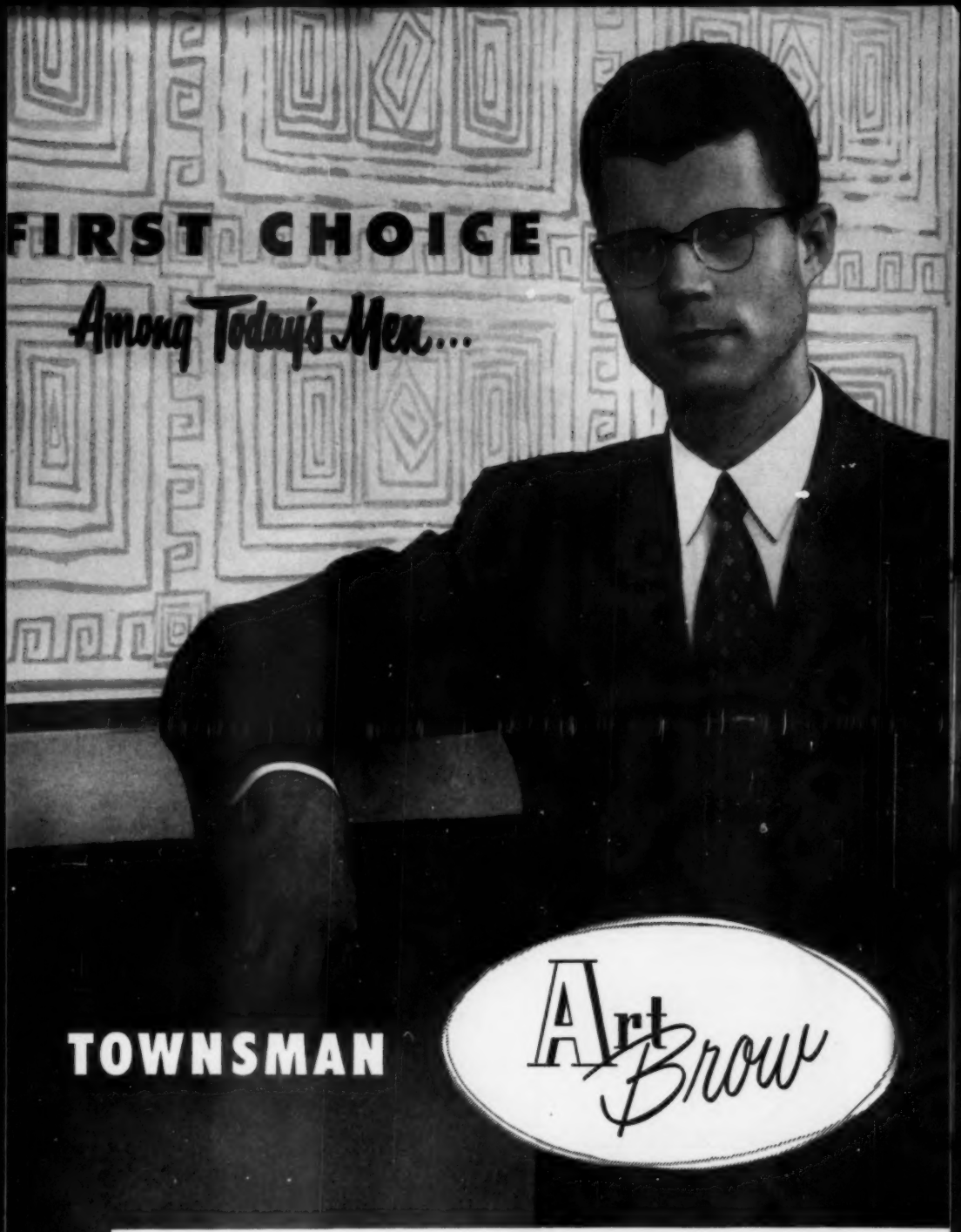

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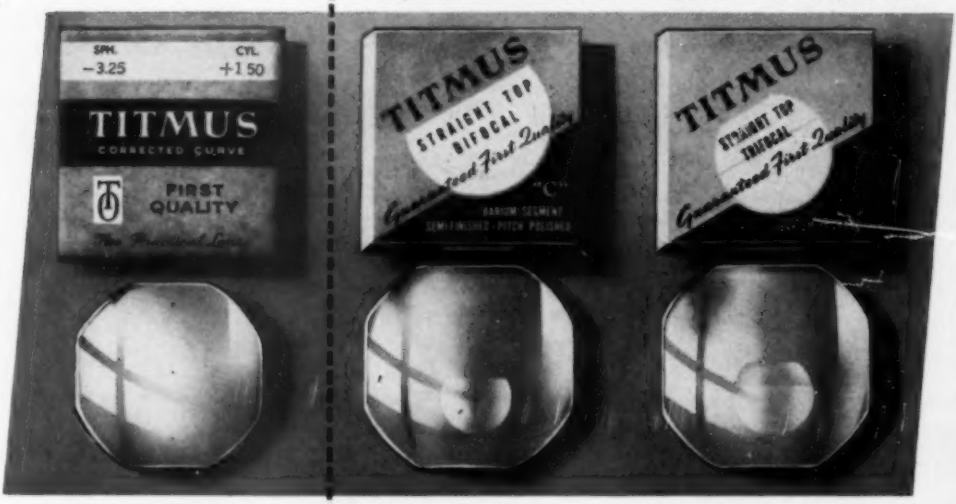

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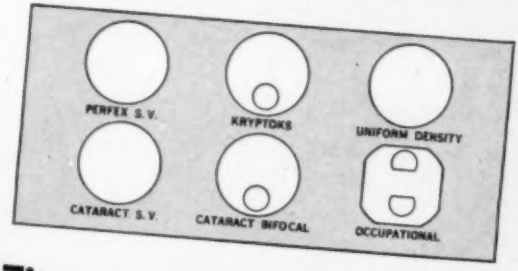

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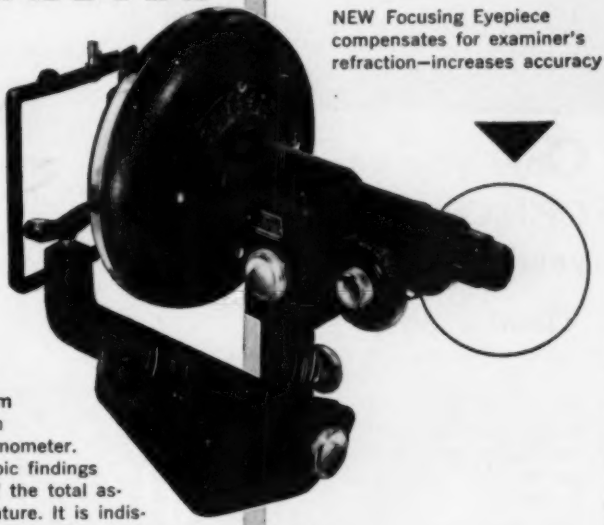

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The Investigation of the Variation and the Correlation of the Optical Elements of Human Eyes

by

Solve Stenstrom, M.D.

Translated from the original German by

Daniel Woolf, O.D.
School of Optometry, Columbia University, New York, New York

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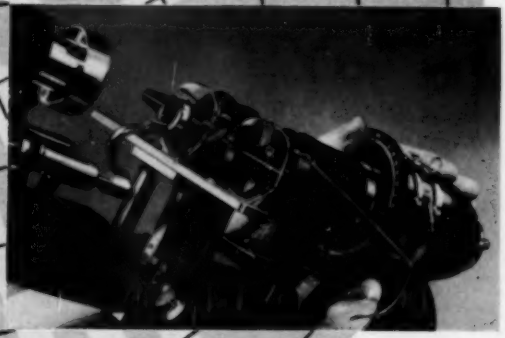

1. Place the ocular side of the lens against the nose of the Lensometer, center, and take a reading. This is the Effective Power of the "distance" portion.

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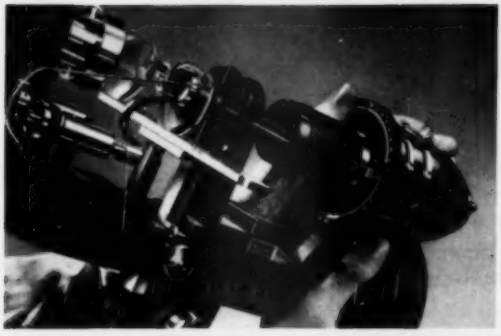
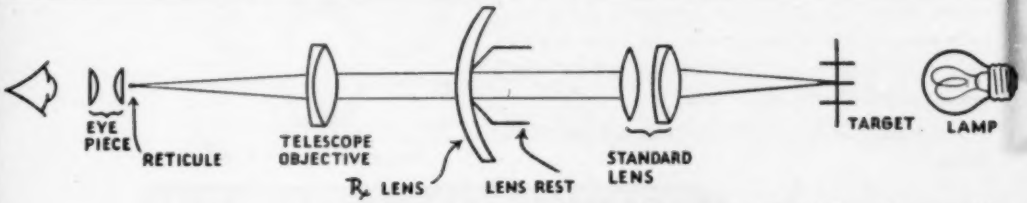


3. Slide the lens down until Lensometer nose is about 6 to 8 mm. *above* the center of the lens. Take Reading No. 1.

4. Slide lens up until Lensometer nose is 6 to 8 mm. *below* center of lens. (Segment is on the nose.) Take Reading No. 2.

5. Subtract Reading No. 1 from Reading No. 2. The difference is the Effective Power of the addition.



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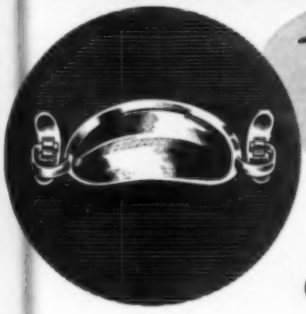

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Vol. 28 September, 1951 No. 9

EFFECT OF SCHOOL EXPERIENCE ON REFRACTION OF CHILDREN*

Monroe J. Hirsch†
Los Angeles College of Optometry
Los Angeles, California

In 1940 Luckiesh and Moss[1] determined the refractive state of 103 fifth and sixth grade school children before and after summer vacation. They used static and dynamic retinoscopy as well as a subjective test and found that there was a slight trend toward more hyperopia during the summer months. While no test of statistical significance was made and the magnitude of the change was not calculated for individuals, the authors stated this trend to be "significant" since it was present in two groups for each of the three tests. More recently (1950) Kephart[2] reported the results of a retinoscopic examination of 84 children before and after the summer vacation period. A change in the same direction as that found by Luckiesh and Moss was noted but the amount was not stated, nor was statistical significance established. The present paper is based upon a similar experiment conducted in conjunction with the visual screening program of the Los Angeles College of Optometry.‡ It is a report of the retinoscopic examinations of 840 children of elementary school age performed in late May and early June of 1950 and again in late September and early October of the same year.

Experimental procedure: Retinoscopy is one of the tests performed as a part of the school visual screening program and the technique has been described by the present author.[3] The procedure involves the use of convex spherical lenses mounted in a spectacle frame to relax the accommodation while the child observes a motion picture cartoon. The examiner, using a bar of lenses, determines the refraction to the nearest quarter diopter in each of the two principal meridians of each eye. In the present study the measure of refractive state is taken as the average value for the refraction in each of the four meridians (two meridians in each eye), i.e., the average of the equivalent spheres for each eye.

*Submitted on June 12, 1951, for publication in the September, 1951, issue of the AMERICAN JOURNAL OF OPTOMETRY AND ARCHIVES OF AMERICAN ACADEMY OF OPTOMETRY.
†Optometrist. Ph.D. Member of faculty. Fellow, American Academy of Optometry.
‡Funds for part of this experiment were made available through a grant by the American Academy of Optometry.

The subjects in the present study were school children attending the three elementary schools in Puente, California. Retinoscopy was performed in all cases by the present author and by Dr. Morton H. Brown, a clinical assistant in the visual screening program. Every attempt was made to have both examiners utilize the same criteria of neutrality of the skiascope motion. No selection of subjects was made, and the present data may be regarded as representing, to as great an extent as possible, a random sample of the school population in a suburban California town.

Results: The results of the two examinations are presented in Table I. The first column expresses the age of the children; the second column, the number of children in each group. The third and fourth columns are the means and standard deviations for the refractions in May or June. All values are plus and hence represent diopters of hypermetropia. Thus, the mean refractive state for the five year olds was 0.83 D. of hypermetropia. The fifth and sixth columns represent the means and standard deviations in September or October. The mean difference is expressed in column seven; a minus sign indicates a reduction in hypermetropia over the summer months. Thus, for the five

TABLE I

Measurements of refraction before and after vacation with significance of differences.

Age (1)	N (2)	May - June, 1950 (3) Mean	(4) SD	Sept. - Oct., 1950 (5) Mean	(6) SD	Differences* (7) Mean	(8) SD	(9) P
5	107	0.83	0.41	0.82	0.47	—0.01	0.38	.85
6	91	0.90	0.58	0.80	0.57	—0.10	0.33	.01
7	89	0.74	0.43	0.66	0.45	—0.08	0.32	.03
8	102	0.76	0.64	0.66	0.72	—0.10	0.36	.01
9	87	0.85	0.53	0.73	0.54	—0.12	0.36	.001
10	90	0.62	0.70	0.60	0.78	—0.02	0.35	.50
11	95	0.59	0.56	0.66	0.56	+0.07	0.35	.07
12	96	0.59	0.65	0.58	0.79	—0.01	0.39	.95
13	83	0.44	0.90	0.36	0.92	—0.07	0.34	.08
Total	840	0.71	0.62	0.66	0.67	—0.047	0.36	.001

*Column 7 gives the mean differences for the ages; 8, the standard deviations of these differences; and 9, the probabilities that differences as great might have occurred by chance. D = post-vacation — prevacation refraction of individual child; N = number of cases; $\overline{D}$ = mean of differences; S_D = standard deviation of differences; $S_{\overline{D}}$ = standard error of mean differences;

$$S_{\overline{D}} = S_D / \sqrt{N}$$

$$t = \overline{D} / S_{\overline{D}}$$

P was found from t table of Fisher entered with N-1. Because of the high correlation between pre- and postvacation refractions on same children, the probabilities cannot be obtained from the means and standard deviations of the two refractions (columns 3, 4, 5 and 6).

year group, the mean refraction before the summer was 0.83 D. of hypermetropia, while the average after the summer was 0.82 D. of hypermetropia and hence the mean difference was 0.01 D. of decreased hypermetropia. The eighth column represents the standard deviation of the differences. The difference was calculated for each subject, and this eighth column represents the standard deviation of the distribution of differences. The ninth column is the probability that a difference as large as that reported in column seven could have occurred by chance in a population in which no difference existed.

Certain general trends in the data expressed in Table I may be noted.

(a) The mean refraction, as in all other similar studies, is negatively correlated to the age. For the period studied the refraction seems to decline from +0.90 D. (six year group, before summer) to +0.36 (13 year group after summer), i.e., the average refraction for the older children seems to be 0.54 D. less hypermetropic than the average for the younger children. Inspection of the Table reveals non-uniformities and, hence, these figures are only approximations. This decline in average refraction over a seven year period represents an average of 0.08 D. per year.*

(b) The standard deviation, as has been pointed out previously by the present author,[4] seems to increase with age. The implications of this, while important, are of no consequence to the present study, other than to indicate that the sample is typical.

(c) The difference in refraction for all age groups except the 11 year olds is in the direction of less hypermetropia or more myopia over the summer months. Many of the differences for individual age groups are significant to the 1 in 100 level, but the difference for the 11 year olds fails to reach significance.

(d) For the total group the trend is toward less hyperopia or more myopia after the summer vacation, and the difference between mean refraction before the summer and after the summer is 0.047 D. This difference is significant to the "less than one in a thousand" level.

(e) The period involved in the present study was about four months, or one-third of a year; the average trend for children of this age is between 0.08 and 0.09 D. less hyperopia per year. Thus, if vacation periods had no effect, it would be expected that about 0.03 D. less hypermetropia would be found after the summer. It has been shown that in the present study 0.047 less hypermetropia was found after

*Former work by the present author (unpublished) yielded an average figure of about 0.08 to 0.09 per year for 3,000 children of similar age to those discussed here.

vacation. This value does not differ significantly from 0.03, the probability that as large a discrepancy could have occurred by chance being 17 in 100.

(f) It seems safest to conclude that there is no difference in the rate of decreased refraction during the summer. The present data show that if there is a difference, it is in the direction of an accelerated rate over the summer. However, the difference being non-significant, the conclusion of no difference is suggested for the present.

An analysis of the individual differences is of some interest. While the average refraction declined over the summer months in the fashion described, it would be well to consider the individual findings. The difference between refraction in May-June and in September-October was calculated for each of the 840 cases. There were 50 cases which exhibited no difference and these were divided equally between the +0.06 and the —0.06 groups. A minus sign (—) indicates a lower refraction after the summer, while a plus sign (+) means that the individual exhibited more hyperopia or less myopia after the summer.

The distribution of the 840 differences is presented in Figure 1. On inspection this distribution seems to be approximately normal with its mean slightly below zero. From Table I it is seen that the mean is —0.047 D. and the standard deviation is 0.36 D. More hypermetropia or less myopia after the summer was found in 354 children (42 per cent) while 486 (58 per cent) showed more myopia or less hyperopia, a difference in percentages significant to the less than one in a thousand level.

It should be clear that each individual difference represents the effect of two factors: the real change in refraction and the errors of measurement. It would be interesting to be able to separate these two factors, but unfortunately this cannot be done from the present data. Since the overall refraction is the sum of the contributions of the various elements, constancy in refractive state during a period of growth indicates symmetrical or compensatory growth of all parts. On the other hand, there is no reason to believe that one part (axis) must grow in advance of all other parts. Thus it is conceivable that refraction might become first more hypermetropic, then more myopic, as first one and then the other element grew more rapidly. The average, however, is clearly toward less hypermetropia. The distribution would seem to indicate that this is true, i.e., some children are becoming more hypermetropic while others are becoming more myopic. Unfortunately, however, the present data cannot be used to prove such an hypothesis.

The data in Figure 1 have been presented in another fashion in

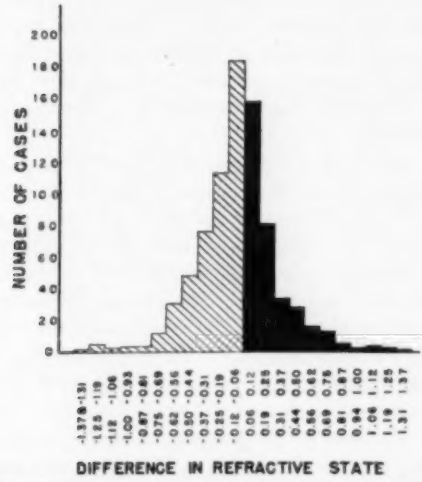

Fig. 1. Distribution of Differences in Refractive State Before and After Summer Vacation—(840 children). Area in black are children whose retinoscopic findings indicated an increased refractive state (more hypermetropia or less myopia) while cross-hatched area represents those whose retinoscopic findings indicated an increase in myopia or a decrease in hypermetropia after the summer.

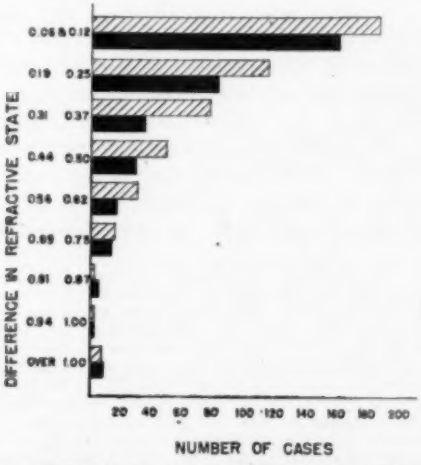

Fig. 2. Differences in Refractive State of 840 Children After Summer Vacation. The black bars indicate the number of cases of increased refractive state (more hypermetropia or less myopia); the cross-hatched bars represent decreased refractive state (decreased hypermetropia or increased myopia).

Figure 2 so that the individual changes may be more easily assessed. Here the degree of change (plus or minus) is expressed as ordinates, while the plus cases and minus cases are shown as two different bars. The abscissae represent the number of cases. It is seen that the trend toward myopia or less hypermetropia exceeded the reverse change for almost all degrees of change.

Refractive data may be presented in two ways. It was common in the past to speak of the percentage of myopes or hypermetropes in a sample. Since there was often a difference of opinion among authors as to what constituted myopia and since percentages are confusing,* this procedure, although apparently simpler, is not as desirable as the alternative. The more suitable method consists of using the degree of refraction, expressing the cases of myopia as minus values and those of hypermetropia as plus values. This procedure has been followed in the preceding analysis. However, since the data of Kephart were expressed as percentages of myopia, it was deemed wise to calculate the present data on this basis for the purpose of comparison. In the following analysis, the criterion of myopia is the use of a minus lens in excess of the working distance lens to obtain neutrality with the retinoscope. It may be noted in passing that Kephart did not state his criterion of myopia, although it may be assumed that since his informants were optometrists, they probably used the same criterion as that used by the present author.

In Table II the percentage of myopes in May-June and in September-October are presented with the data of Kephart included for comparison. Since Kephart used grade in school instead of age, it is assumed that age six corresponds to the first grade, seven to the second grade, etc.§

From Table II the following observations may be made:

(a) The present author found 68 myopes before the summer and 70 myopes after the summer, or a slight increase in the incidence of myopia. Kephart, on the other hand, found 41 myopes before the sum-

*An example of the danger inherent in the use of percentages is found in Kephart's paper. This author reports 67 per cent of the 8th graders to be myopic in May, while 33 per cent were myopic in September. Thus there was a decline of 34 per cent in the incidence of myopia. However, since there were only 3 cases in this group, it becomes clear that the 34 per cent decline was one case. It should be stressed that this is not an instance of intentional deception; the author stated the number of cases and made no attempt to conceal data, but there is a tendency for the reader to misinterpret.

§It is interesting to note that in the literature, almost without exception, those who adhere to the theory of school work as a cause of myopia express results in terms of grade in school, while the adherents to the biological theory use chronological age. Thus, from the very outset one group thinks in terms of environment (grade in school), while the other thinks in terms of growth and maturation (age). The jump to cause and effect based on association which will be mentioned presently is thus facilitated.

TABLE II

Number and percentage (in parenthesis) of children at each age or grade level classified as myopic on retinoscopic examination at two testing dates.

	HIRSCH			KEPHART			
	Number and Per Cent Myopic			Number and Per Cent Myopic			
Age	N	May-June	Sept.-Oct.	May	Sept.	N	Grade
5	107	4 (4)	3 (3)	-------	-------	---	---
6	91	2 (2)	4 (4)	-------	-------	---	---
7	89	5 (6)	5 (6)	1 (7)	0 (0)	14	2
8	102	4 (4)	6 (6)	2 (22)	3 (33)	9	3
9	87	2 (2)	5 (6)	2 (40)	2 (40)	5	4
10	90	9 (10)	8 (9)	4 (35)	2 (18)	11	5
11	95	8 (8)	6 (6)	5 (55)	3 (33)	9	6
12	96	15 (16)	15 (16)	6 (67)	4 (45)	9	7
13	83	19 (23)	18 (22)	2 (67)	1 (33)	3	8
				8 (89)	3 (33)	9	9
				8 (89)	4 (44)	9	10
				3 (50)	3 (50)	6	11
Total	840	68 (8.10)	70 (8.33)	41 (49)	25 (30)	84	Total

mer and only 25 after the summer.

(b) There is an increased incidence of myopia with increased age (or grade in school) which has been found by both authors. However, while the trend is the same in both instances, the quantities are very different. Hirsch finds an increase from two to four per cent for the younger group to about 22 or 23 per cent for the older. Kephart finds an increase from zero to seven per cent in the lower grades to as high as 89 per cent for two of the upper grades.**

(c) The cause for the discrepancy in the findings of the two authors may lie in the differences just mentioned. It is clear that no population, randomly selected, exhibits 89 per cent of myopia. The percentage of myopia in the adult population in the United States does not exceed 30. It is therefore almost certain that Kephart's data either do not represent random selection, or if random sampling was used, a fluke has occurred.

Discussion and Conclusions: The present problem is of importance in the question of the genesis of refractive errors in general and myopia in particular. For the past 30 years two opposing theories have been held for the causation of myopia. One of these, stemming from the work of Cohn,[5] has been referred to as the "use-abuse theory" by E. V. L. Brown[6] and suggests that use of the eyes, especially in near work, is the major cause of myopia. The other theory, first clearly enunciated by Steiger,[7] states that myopia, at least of lower degree, is

**The figures of Hirsch presented here are in close agreement with others found on 3,000 Ohio children. Seemingly, the percentage of myopia increases from approximately 2 or 3 per cent among six year olds to about 25 per cent for those past puberty and between 25 and 30 per cent for adults.

a result of normal biological variation and is to a minor degree or not at all affected by such environmental factors as use.

Kephart has concluded from his results that: "Over the summer vacation period the percentage of myopia decreases indicating a recovery from the myopic trend resulting from school experience." This evidence would favor the use-abuse theory, and Kephart, in assuming that the myopic trend *results* from school experience, espouses such a theory. Hirsch[8] has recently re-stated the danger of the well-known error of confusing association or correlation with cause and effect. While it is possible to demonstrate association, it is not possible to prove cause and effect on such a basis. Thus, the statement of Kephart that myopia results from school experience is not valid. The fact is that myopia increases in the upper grades of school, but factors other than school experience may be causative.

The objection to Kephart's statement is obviously not essential to the present discussion since it has been stated that the results of the present study were in the opposite direction, and hence Kephart's conclusions are questioned. It is, however, important to realize that even were myopia to decrease over the summer, proof of near-work as a cause of myopia would be lacking. Association on the one hand and cause and effect on the other must be differentiated. The objection to this type of reasoning is here mentioned because of its importance to optometric science in general.

The discrepancy between the data both of Kephart and of Luckiesh and Moss from that of the present author requires some explanation. It has been clearly demonstrated in the present study that the average refractive state decreases during the summer just as it does during the remainder of the year, and that the "myopic trend" does not halt or reverse when the child is on vacation but rather continues at a similar or accelerated rate. How, then, can we account for these opposite findings by the present author and by two earlier investigators? No complete explanation can be offered, but the following points are suggested as possibilities.

(1) The number of children investigated differed markedly. The present study included 840 children, that of Kephart, 84, and that of Luckiesh and Moss, 103. While numbers alone do not account for the difference, in the absence of a demonstration of statistical significance, the number of cases must be considered.

(2) The data of Kephart are completely out of line with what one expects to find in a random sampling of the school population. It is inconceivable that 89 per cent of any school grade would exhibit

myopia. The present author is aware of no studies on American school children which have found more than 30 per cent of myopia among the older age groups. Even clinical and private practice data, which would be weighted in the direction of more myopia do not exhibit figures anywhere near the magnitude of those of Kephart.

(3) The present study was conducted by two retinoscopists who attempted to use similar criteria, and the statistical analysis was performed by one of these optometrists. Kephart and Luckiesh and Moss were scientists analyzing the results obtained for them by optometrists who were not aware of the statistical procedure. Thus discrepancies could occur due to lack of rapport between the statistician and the examiner. In the case of Kephart's data, for example, it is possible that the criterion of myopia (not stated in the paper) might have been something other than the usual.

(4) Most important is the fact that neither Luckiesh and Moss nor Kephart demonstrated that their results were statistically significant. In the absence of such evidence, and in view of the presence of a high level of significance in the present study further attempts at explanation seem unnecessary. For 11 year olds, the present author found as did Luckiesh and Moss, a change in the direction of more hyperopia over the summer. This group was as large as that used by Luckiesh and Moss. The difference found by the present author was, however, not statistically significant, i.e., it could have occurred by chance. It would then seem very possible that the results of Luckiesh and Moss may also have been non-significant, and no different from zero difference. If this is the case, and pending the appearance of other data we must conclude that it is, then it nicely shows the danger of omitting an analysis for statistical significance. It is most unfortunate to build magnificent theories of myopia causation on weak evidence.

Conclusions: On the basis of the 840 randomly selected cases in the present study, the following conclusions about the general theory of myopia causation may be drawn:

(a) Between the ages of six and 13 the average refractive state manifests a decreased hypermetropia at the rate of about 0.09 D. per year.

(b) This rate is just as rapid during the summer months. In the present study the rate was more rapid during the summer, but by an amount which did not achieve statistical significance.

(c) *If* all other things are equal during summer and winter except for the amount of close work done by the child, then close work has no association with change in refractive state.

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ABSTRACTS

THE PROBLEM OF THE POOR READER. Arthur Jampolsky, M.D., (San Francisco, California). Digest of Ophth. & Otol., 13(9), 538-542, July, 1951.

This paper which appeared originally in *California Medicine*, April, 1951, divides poor readers into two groups: those who have a *specific* reading disability and those in whom the disability is *nonspecific*. The former is caused by a confusion in the recognition of language symbols and it is usually associated with ambidexterity, comparative clumsiness, and an exaggerated persistence of the norml childhood tendency to reversal of letters and symbols.

In the *nonspecific* group the lack of progress in reading may be due to low intelligence, lack of interest, insufficient readiness to read, ocular anomalies, hearing defects, emotional problems, and other obstacles to learning. It is important to recognize *specific* reading disability early since then more direct attention may be given on the reading problem and alternative methods of teaching may be used. However, if the child is found *not* to have a specific reading disability, then consultants must determine which of the factors, mentioned above, require attention. In cases of *nonspecific* reading disability the emphasis should be placed on an investigation of the physical and emotional obstacles.

Prophylactic measures may be carried out in the field of reading problems in purest and simplest form by combining phonetic, kinesthetic, and visual methods in the teaching of reading skills.

R. E. B.

CONVERGENCE. AN INVESTIGATION INTO THE NORMAL STANDARDS OF AGE GROUPS. A. Mellick. Brit. J. Ophth., 33(12), 755-763, Dec., 1949.

A survey of the literature indicates that there is considerable variation as to the normal values for horizontal ductions. The present investigation is an attempt to establish the normal range of horizontal ductions. The procedure used is clearly and completely outlined.

The subjects consisted of 561 individuals free from gross ocular disease, heterophoria, and ametropia above 4 D. The ductions were taken by both the variable prism stereoscope and the synoptophore using two types of targets; a flat target of letters and a stereoscopic target of the bucket type. The results are tabulated comprehensively and statistically analyzed according to the instrument used; the target used; distance and near; and according to the age groups.

R. E. B.

A BIREFRINGENCY PHENOMENON OF THE CORNEA AND LENS*

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This paper reports the observation by the writer of an objective interference effect in the cornea and lens which is attributed to double refraction in those media. The effect and the method of observation are described as well as the possible relation of the effect to previous investigations of polarization in the eye. A search of the literature has disclosed no previous reference to the phenomenon. In the presentation the writer assumes the reader is already familiar with optical crystallography.

INTRODUCTION

Since the early nineteenth century it has been recognized that certain media of the eye can polarize light. Helmholtz theorized that the partial polarization responsible for the entoptical phenomenon of Haidinger's brushes was due to double refraction in the radial fibers comprising Henle's fiber layer of the macula.[1] In this connection Wood[2] as well as Helmholtz has remarked that most organic fibers and membranes are birefringent as a result of their elongation in growth. Jamin proposed a second explanation for Haidinger's brushes which suggested that the laminar structure of the lens was crucial.[3] Jamin's explanation is not so convincing as that of Helmholtz, yet double refraction is demonstrated by the lens and by the cornea as well. The present writer has observed in both the lens and the cornea the interference pattern, or isogyre, unique to doubly refracting media.

OBSERVATION OF THE EFFECT IN THE CORNEA

When the cornea is directly illuminated by plane-polarized light and at the same time examined through a crossed polarizer, or analyzer, a variable pattern of light and shadow will be observed in the cornea or projected against the iris. When the axes of the polarizer and the analyzer are at right angles the shadow pattern will assume the shape of a dark cross set in a light field. Since the dark aperture of the pupil is in the central part of the background for this figure the intersection of

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†Optometrist.

the cross will not be seen. All that will be seen are the projecting arms of the cross in contrast to the lighter background of the iris. The arms will appear as four spokes of the pupil, Figure 1. Close attention to

Fig. 1. The corneal isogyre in situ.

the transparent periphery of the cornea adjacent to the limbus will, in most cases, disclose a concentric dark ring, either partial or complete. If the examination is made with white light the ring will be seen to vary in color from its inner margin where it is red, through black, to its outer edge where it is blue.

Rotation of the analyzer alone will cause a reversal of light and shadow in the above described pattern. The reversal is complete when the axis of the analyzer parallels that of the polarizer. The pattern is then one of a light cross and circle against a dark field.

When both the analyzer and the polarizer are rotated through an equal angle and in the same sense, the cross will not change in appearance, as is the case in reversal, but will be seen to rotate in the same direction as the polarizing system and to the same degree.

The effect as it has been described will be to some extent modified if the light source of the observer, or both, are not close to the optic axis of the cornea.

The reader who is familiar with optical crystallography will already have recognized this description as that of the isogyre, the interference pattern observed in birefringent uniaxial crystals when these crystals are placed in highly convergent light. The formation of isogyre is extensively treated in Wahlstrom[4] and in Jenkins and White.[5]

When this relation is made several of the observed characteristics of the corneal figure are more meaningful. The spokes are the brushes and the concentric ring is the first interference ring of the isogyre. The

rotation of the cross with the polarizing system takes place around the crystal axis only and therefore indicates that this axis coincides, at least approximately, with the optic axis of the cornea and eye.

The optical path of the polarized light, when the observation of the cornea is made in situ, can be easily analyzed. The plane-polarized light directed into the eye is rendered highly convergent by its refraction at the first surface of the cornea. This plane-polarized cone of light is reflected from the iris back through the cornea. The cornea, or some layer of the cornea, possesses the properties of a uniaxial crystal or array of parallel crystals. The emergent light is made parallel by refraction at the surface of the cornea and is transmitted through the analyzer. Thus we have a folded optical system similar to the straight one used in petrographic microscopes.

On first consideration one might question the effectiveness of the irregular surface of the iris as a non-depolarizing reflector. However, whatever light is reflected from the iris back through the system is specularly reflected from small surface increments and retains its polarized character.

The folded system can be demonstrated by placing on a piece of black velvet, simulating the iris, a plane parallel plate cut from any of the large artificial birefringent crystals. The crystal axis must be normal to the plane surfaces. The author used a section of an ammonium dihydrogen phosphate crystal. On this is placed the flat surface of a strong plano-convex lens. The convex surface of the lens together with the crystal corresponds to the cornea. The plane-polarized beam of a collimating microscope lamp is directed into the lens only slightly oblique to its axis. When the model is observed through an analyzer the isogyre stands out sharply, its size determined by the curvature of the lens.

Direct observation of the isogyre can also be made when the excised cornea is placed between crossed polarizers. Figure 2 is a photograph of the isogyre in the freshly prepared cornea from a cow's eye. The pattern is obscure due to the clouding of the post mortem preparation and the poor optical surfaces of the excised cornea.

OBSERVATION OF THE ISOGYRE IN THE LENS

Although no optical system has been devised to obtain the lenticular isogyre in situ, as with the cornea, it can be seen in the excised lens. Figure 3 shows a photograph of the isogyre in the excised lens of a cow's eye. The pattern is smaller and sharper than that of the cornea because of the high refracting power of the crystalline lens in air. The first interference ring is quite apparent in the photograph. As in the

Fig. 2. The corneal isogyre in the excised cornea of a cow's eye.

cornea the birefringent optic axis coincides with the optic axis of the lens and the isogyre rotates with the rotation of the polarizing system.

In the crystalline lens the lens fibers are arranged with their long dimension in the anterior-posterior direction, parallel to the optic axis of the lens. The birefringent optic axis of organic fibers, when they are double refracting, parallels the long dimension of the fiber. This places the birefringent axis of the collective lens fibers, the lamellae, parallel to the optic axis of the lens. We have already observed that both the corneal and lenticular isogyres rotate about the optic axis of these elements and concluded that the birefringent axis coincided with the optic axis. Now we have a histological explanation.

BIREFRINGENCE DUE TO STRAIN

So far the explanation of the corneal and lenticular isogyres have been based on the premise of a natural crystalline structure of those

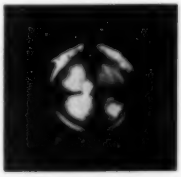

Fig. 3. The lenticular isogyre in the excised lens of a cow's eye.

media. However, double refraction also takes place in otherwise isotropic media. This principle has been widely applied in the strain analysis of engineering models using polarized light. Similarly in the cooling and annealing of large glass discs the disc develops birefringency.[6] When the large disc cools the exterior, principally the edge, cools first while the center remains plastic. As the center cools and contracts it tends to pull away from the hardened shell. This creates a radial tensile strain in the glass. As a result of the strain the glass has two indices of refraction, one radial and one tangential, closely analagous to the ordinary and extraordinary indices of uniaxial birefringent crystals. The strained glass disc yields an interference pattern identical with the crystal isogyre when placed between crossed polarizers.

This implies a second possible explanation of the corneal and lenticular isogyres. There may develop in the growth of these elements a radial strain responsible for double refraction and the consequent birefringent interference pattern we have described.

Unfortunately, the only check of this second hypothesis to date has been a rather gross one. If the birefringency of the cornea is due to strain, an increase in strain would change the amount of birefringency and there would be a concomitant increase or decrease in the diameter of the interference rings of the isogyre. One way of stressing the cornea is to increase the intra-ocular pressure. This was done simply by pressuring the eyeball while the isogyre was being observed, taking care not to deform the eyeball at a point that would cause irregular distortion of the cornea. The results were negative, no contraction or expansion of the interference ring could be seen. There is, of course, no way of checking the distribution of the added stress.

CONCLUSION

Although we have conclusive evidence of the birefringency of the cornea and lens it seems unlikely that it can be related to other polarization effects of the eye.

Only one remark in the history of these phenomena is noteworthy and that is by Haidinger. We have already alluded to Helmholtz' theory of Haidinger's brushes but Haidinger also described a second entoptical phenomenon of polarized light. This figure, he said, had the shape of a cross. Although no other investigator has ever duplicated his observations anyone familiar with the elusive nature of entoptical effects will be cautious in discrediting Haidinger's unique result. Nevertheless, assuming the retinal projection of such a cross it is still doubtful that it could be related to the isogyres since some anomaly in the

refraction of the eye would be required to form an image of either the cornea or the lens on the retina.

The results of Neuberger's recent experiment with Savart's double plate suggests a second locus of polarization in the eye separate from and additional to that postulated by Helmholtz in his explanation of Haidinger's brushes.[7] The direction of the birefringent axis of the cornea and the lens parallel to the optic axis of the eye precludes the possibility that this second source of polarization lies in the double refraction of these media.

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REVIEW

REFERENCES ON VISION. (Collected and card-indexed by Lighting Research Laboratory, General Electric Co.) Mimeographed by the Naval Medical Research Institute, National Naval Medical Center. Bethesda, Maryland. 4 Vols., March 1, 1943.

As acknowledged in the Introduction, these references are a portion of the file developed over a period of 35 years by Lighting Research Laboratory of General Electric Company, Nela Park, Cleveland, Ohio, under the direction of Dr. Matthew Luckiesh and his long-time colleague, the late Lieutenant Commander Frank K. Moss. Dr. Luckiesh authorized the Naval Medical Research Institute to copy this reference file for its use.

The references are indexed according to subjects. Volume I contains references on subjects from "Aberrations to Compensation:" Volume II "Dominance to Irradiation:" Volume III "Kinematics to Ret-Potential;" and, Volume IV "Scotopic to Vitamin." Many of the references are from the PSYCHOLOGICAL ABSTRACTS, ophthalmological and optometric journals, illuminating engineering journals, and other scientific publications. This compilation of references on vision and seeing prior to 1943 is useful to research workers, teachers and writers.

ROBERT E. BANNON.

A CASE REPORT OF INTRACRANIAL TUMOR WITH VISUAL COMPLICATIONS AND COMMENTS ON THIS CONDITION*

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Visual fields play a vital but often neglected role in ocular diagnosis. The following case report is presented to demonstrate the value of visual fields in suspicious cases.

On November 26th, 1949, the patient presented himself for examination. He was a white male, 52 years of age, obese, in apparent good health and employed as a painter. His physical condition, both past and present, was said to be good and his chief complaint was a gradual loss of vision in the right eye and frontal headaches which were evident every day and ranged in severity from moderate to extremely severe. The patient reported that a day rarely passed without his taking from two to eight aspirin tablets and the headache was not appreciably relieved by this self-medication. It was reported that the headache and the diminution of acuity began at the same time and acuity has become gradually poorer for about one year. The patient also complained of the usual presbyopic symptoms.

Visual Acuity: O.D. 20/100. O.S. 20/20.

Versions and rotations and the pupillary reflexes were normal and the external examination was negative.

Ophthalmoscopy: The media was clear and the fundii appeared normal except for a very slight pallor of the disc of the right eye. The departure from the normal was so questionable that a tentative diagnosis of "possible optic atrophy" was made.

Refraction resulted in the following prescription:

O.D. + 0.25 D. cyl. axis 90 V.A. 20/100. O.S. + 0.25 D. sph. V.A. 20/20. Add + 1.75 D. sph. O.U.

The peripheral field disclosed a loss of a portion of the superior temporal area of the right eye, while the peripheral field of the left eye was normal. The central fields and blind spots were charted on the stereocampimeter and it was found that the blind spot of the right eye was elongated in the vertical meridian. The blind spot of the left eye was normal. Both central fields were otherwise normal.

In view of the suspicious fundus picture, the reduction of acuity

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and the loss of a portion of one visual field, the patient was referred to an ophthalmologist who, in turn, referred him to a radiologist.

On December 15, 1949, the patient returned to the writer with a series of x-ray films and a report from the radiologist that the plates were negative. At this time it was suggested that a further check of the visual fields and the acuity be made. The visual acuity was now O.D. 20/200. O.S. 20/20.

The fundus picture was the same as it had been at the previous examination. The peripheral fields revealed a more extensive loss of the superior temporal portion of the right eye and a superior temporal loss of the left eye.

Diagnosis: There were several conditions to be considered, the three most likely being aneurism, lead poisoning, which was a possibility due to the patient's occupation, and tumor. In aneurism the onset is sudden and the pupil is usually widely dilated. There is sometimes a history of cardio-vascular disease, the optic nerve head is often normal or shows papilledema, but there are occasionally bitemporal field defects. Lead poisoning presents a definite occupational hazard to the painter and the possibility of its occurrence had to be considered. The patient exhibited none of the general symptoms such as muscular weakness and abdominal colic, but his persistent headache, a vague symptom at best, was suspicious. Other more definitely diagnostic ocular signs of lead poisoning such as paralysis of the extraocular muscles, lead incrustation of the cornea and conjunctiva, and bilateral loss of vision were absent, ruling out the possibility of lead poisoning.

All symptoms at this point indicated a chiasmal involvement of long standing with a slow and gradual progress, particularly so since the second peripheral field study revealed a bitemporal field involvement. The slight optic atrophy, the negative x-rays and the bitemporal field defect combined to present a picture of Cushing's syndrome, which is usually indicative of chiasmal tumor.

The patient was made aware of the seriousness of his condition although the actual diagnosis was withheld from him. His family physician, who was also a friend of his, was called and told of the suspected diagnosis. The patient was immediately referred to the neurology department of a local hospital and was admitted on January 3, 1950, for an investigation of gradual loss of vision in the right eye in the preceding nine months. According to a detailed hospital report sent the writer, he was seen by the eye and neurosurgical departments, at which time the vision in the left eye was 20/25, and he could count fingers at two feet with the right eye. X-rays of the skull at that time

were negative. It was the opinion of the neurosurgical staff at that time that a neoplasm in the region of the optic chiasm was a good possibility.

The general physical examination revealed nothing of significance, except for severe dental caries and an upper respiratory infection. Neurological examination was not remarkable except regarding the eyes.

Accessory clinical findings: Blood, urine and serologic tests revealed no abnormalities. Spinal fluid studies were normal. X-rays of the skull and chest revealed no significant abnormalities. X-rays of the paranasal sinuses revealed a moderate degree of cloudiness of the ethnoid and antra and considerable thickening of the cellular septa of the sphenoids.

Course in the hospital: At the time of admission the patient showed definite progression of his disease in that he had suffered further visual loss and also had demonstrable optic atrophy in O.D. by ophthalmoscopic examination. Diagnostic procedures were postponed for almost two weeks due to the upper respiratory infection and sinusitis. On January 16, 1950, bilateral cerebral angiography and pneumoencephalography were attempted under sodium pentothal. The arteriogram was unsuccessful, and no air entered the ventricular system. On January 20, 1950, bilateral cerebral arteriography by the open method was carried out and no significant abnormalities were found. On January 23, 1950, ventriculography was carried out and no definite evidence of tumor was seen. However, due to strong suggestion of neoplasm, a right frontal craniotomy was carried out following ventriculography and a meaty tumor, approximately 2 cm. in diameter was removed from the tuberculum sellae. This tumor compressed the optic chiasm and the right optic nerve. The gross appearance of the tumor was that of a meningioma. The pathological report confirmed the clinical impression. The post-operative course was relatively uneventful and the patient made a complete recovery from the operation with no neurological residuals.

The vision was immediately improved. Two weeks following the operation vision in the left eye was 20/20 and in the right eye 20/40-2. There was an increase in the size of the left peripheral field and decrease in the sector defect. There was a superior temporal defect in the right eye. The studies demonstrated striking improvement in visual function. Patient was also seen by the dental department and the extraction of his remaining teeth was carried out. He was discharged February 15, 1950, with instructions to return to the eye department on March 14, 1950, for repeat visual studies. He was to be seen by the neurosurgical department as an out-patient for evaluation when the

eye consultation is completed. Final diagnosis: Meningioma-Tuberculum sellae. Treated, operated, improved. Chronic pan-sinusitis. Treated-improved.

On May 1, 1950, the patient was again examined by the writer. At this time visual acuity was 20/20 O.D., O.S., and O.U. The left visual field revealed no deviation from the normal while the right visual field revealed a slight (between 5 and 10 degrees) superior temporal contraction. From these findings it was reasonable to assume the operation a complete success and the prognosis excellent.

COMMENTS

It is not within the responsibility of the optometrist to diagnose cranial tumor, but in certain instances it is possible for him to do so, and more often, to direct suspicion to that particular phase of brain pathology. Quite frequently a tumor, due to its size and location, will manifest itself first through definite ocular signs and symptoms, and by familiarizing himself with these signs and symptoms the optometrist can at least suspect tumor, and by prompt referral to a neurologist may often save the patient's vision and possibly his life.

Dorland[1] describes tumor as a swelling; a morbid enlargement; a mass of new tissue which persists and grows independently of its surrounding structures, and which has no physiologic use. Tumors are divided into two classifications, benign, which is an innocent type of tumor not likely to recur after removal, and malignant, which is one likely to recur and eventually to destroy life. Tumors, benign and malignant, are further subdivided according to location, structure, shape, and tissues involved. The optometrist is not, however, concerned with the pathology and histopathology of the tumor, but merely with its presence as it involves ocular function.

Chamlin[2] states that visual field studies assume an important place in diagnosing and localizing brain tumors. Since the normal field depends upon the integrity of the visual pathways, any interference with these pathways will cause defects in the visual fields. The visual pathways may be encroached upon by direct pressure or by an obstruction to the flow of cerebrospinal fluid.

Lesions in the visual pathways often cause recognizable changes in the fundus picture, but when ophthalmoscopy is negative, diagnosis of the existence of such lesions depends upon changes in visual acuity, the visual fields, and the presence of abnormal visual sensations. In examining the visual acuity light sense and dark adaptation should also be tested. Tumors directly involving the retina may be divided into two general classifications, those which involve the rods and cones, and those involving the nerve fiber layer. When the ganglion cells are

involved and the nerve fiber layer is unaffected, the defect in the visual field corresponds to the defect in position, shape and extent. Traquair[3] states that in these involvements there is a greater loss of the blue field than the red. The situation is exactly reversed when the nerve fiber layer is involved. When the rods and cones are involved field defects are exaggerated when the visual fields are plotted under subdued illumination. In involvements of nerve fibers of the retina the defect in the field does not conform to the size and shape of the lesion, but to the size and shape of the fibers which are involved. A small lesion near the optic disc may show an extensive field defect, while a small lesion in the periphery may produce a field defect difficult or even impossible to chart. Visual field defects which arise as a result of optic nerve involvement are similar to those arising from retinal lesions.

A rare form of syndrome[4] which is the manifestation of a tumor pressing on the optic nerve is known as the Foster Kennedy syndrome. The syndrome of Foster Kennedy occurs most often with frontal lobe tumors and olfactory meningiomas. The symptoms consist of homolateral optic atrophy with central scotoma, absence of smell, and contralateral papilledema. Here the fundus involvement alone would indicate that the patient is to be referred at once.

Possibly the most important site of tumor from a visual pathway point of view is the chiasm.[5] The one distinctive feature of chiasmal involvement is some form of bitemporal hemianopsia and, furthermore, the bitemporal field defects may be peripheral, central, or peripheral and central. Bitemporal hemianopsia occurs chiefly as the result of cerebral tumor. Prechiasmal tumors characterize themselves by a gradual development of blindness in one eye and later a temporal field defect in the other eye. Hence an unexplained loss of acuity in one eye cannot be shrugged off with a diagnosis of amblyopia exanopsia, and a careful field study should be made in these cases.

Tumors involving the trigeminal nerve and especially the Gasserian ganglion are common, and one of the first symptoms in corneal anesthesia.[6] Nystagmus is frequently a symptom in III and IV nerve tumors, a tumor which does not occur frequently. There are also times when a nystagmus, present from a condition other than the one under discussion, is abolished by a tumor of the parietal lobe. In pineal and quadrigeminal tumors paralysis of associated vertical movements of the eyes is often observed, and paralysis of convergence is a frequent concomitant. The pupillary reflexes to light may also be impaired.

In some lesions affecting the body or anterior angle of the chiasm changes in the optic disc do not occur for six to seven weeks. In tumors of postchiasmal origin the optic disc will appear normal for a consid-

erable length of time, even for years after the onset of blindness.[4]

Alexia, or word blindness, may occur in association with injury, cerebral vascular accident, or cerebral tumor. This term is used to describe disturbances in reading not due to a reduction in visual acuity. Alexia varies greatly, from complete alexia to reading with difficulty, poor comprehension and early fatigue. Within these limits may be ability to read several letters but no words, ability to read correctly without understanding, ability to read most letters but no words, ability to read most words, and able to read but with partial understanding. Also occurring as a result of retinal changes, micropsia and macropsia are also considered the result of cerebral involvement. Micropsia occurs more frequently than macropsia as a manifestation of cerebral involvement.

There is controversy in the literature as to the importance of visual hallucinations relative to brain tumor. While visual hallucinations arise also in patients who are drug intoxicated and in psychopaths, Walsh[4] states that such hallucinations as images of people and objects and flashes of light and zig-zag lines are frequently associated with cerebral tumors. This is particularly true of tumors of the temporal lobe.

Moench[7] reports that brain tumors may first show up as migraine headache. Typical headaches, nausea and an interference with vision may persist for years before a diagnosis of cranial tumor is made. He further states that no chronic headaches should be dismissed before the possibility of brain tumor has been investigated. Headache, however, is seldom the sole symptom. Diplopia, loss of acuity and reflex changes are other superficial symptoms of interest to the optometrist. The headache is usually sharp, severe and continuous, and is often worse at night. It is often precipitated by sudden changes in posture, stooping, straining, and jolting. Moench[7] further summarizes that one in every 200 deaths can be attributed to brain tumor, and that it can occur at any age. Its onset is gradual, but abrupt when associated with hemorrhage. In tumors resulting in an obstruction to the cerebrospinal fluid an increase in the intracranial pressure due to the obstruction causes papilledema, an important fundus change in the diagnosis of cranial tumor.[8] Papilledema is described as choked disc, and is an optic neuritis due to intracranial pressure and without inflammatory manifestations. Duke-Elder[9] states that a rise in intracranial pressure is by far the commonest cause of papilledema and 80 per cent of all brain tumors are associated, in one stage or another, with papilledema. In cerebellar tumors it develops rapidly; in cerebral tumors it is usually late in appearance and slow in evolution. Papilledema is nearly always bilateral

and of little value in localizing the laterality of the lesion. Examination of the fundus in papilledema shows great swelling and protrusion of the disc, marked distortion and tortuosity of the retinal veins and hemorrhages at or near the disc.[10] The degree of projection of the disc is measured by the dioptric difference of the ophthalmoscopic lens in viewing the most protruding portion of the disc and some nearby unaffected portion of the retina. Therefore if there is a dioptric difference of 3 diopters the condition is referred to as 3 diopters of papilledema. Usually papilledema measures about 2 diopters, but cases have been observed in which the protrusion is as great as 9 diopters. In the early stages there is little or no impairment of vision, but the blind spot is always enlarged.

The second significant fundus characteristic of cranial tumor may be simple optic atrophy. The ophthalmoscopic picture is that of a pale, white nerve head with well-defined borders. In border-line cases a reduced central visual acuity and defects in the central visual fields will often establish the diagnosis of simple optic atrophy.[4]

It is not the intention of the writer to encroach upon the field of the neurologist because with his neurologic examination, blood counts, complement fixation tests, urine analyses, roentgengrams, ventriculography, lumbar punctures, examination of the spinal fluid and encephalography he is admirably equipped for that task. However, since the optometrist does have a preponderance of patients who suffer from headache, loss of acuity, and other more vague ocular symptomatology which may well be indicative of brain tumor, it is well that the optometrist be alerted to recognize those symptoms, and on finding them, to intelligently refer the patient for proper medical study.

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SUBJECTIVE APPRAISAL OF COMFORTABLE BRIGHTNESS RELATIONSHIPS*

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The importance of the brightness characteristics of various areas of the visual field has long been recognized. Current recommended practices of interior lighting emphasize that there should be no compromise with quality of lighting and considerable space is devoted to discussions of how to achieve comfortable brightness relationships. Unfortunately, the relatively meager data of the evaluation of comfort and ease of seeing result only in qualitative conclusions and relationships. Thus, it often has been difficult, and sometimes even impossible, to determine directly the degree to which those conditions or factors contribute favorably or unfavorably to the comfort of a visual environment. The common plaint of "too much light" usually indicates that the quality of lighting has been neglected. In most cases there is not too much light, but, rather, the brightnesses of certain areas are out of balance. The average person realizes that he is uncomfortable and grasps at the most (to him) tangible reason for his visual discomfort. Therefore, it is necessary to fill the gap in our overall knowledge by additional comprehensive and quantitative investigations which can be correlated with lighting practice.

Glare is the obvious and offensive result of improper brightness relationships within a visual environment and is recognized as such. Exposure to lesser brightnesses can be, and often is, just as effective in producing decreased ease of seeing, even though there may be no apparent reduction in visibility. Therefore, the appraisal of brightnesses in the visual field should preferably be at some level below that which is obviously undesirable.

Many years ago, Luckiesh and Holladay[1] attempted to appraise the psychophysiological effects of glare and developed a scale of comfort-discomfort or "degrees of sensation" ranging from a scarcely noticeable sensation to intolerable and painful sensations. However, their investigation was limited in scope and has been difficult to apply directly to the evaluation of specific lighting installations.

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Any comprehensive investigation of environmental brightness relationships necessarily requires consideration of the many factors which govern whether the visual environment is comfortable or uncomfortable. For convenience, these factors may be divided into two groups. The first group involves those that may be considered basic and fundamental such as:

1. The brightness of the source or luminous area.
2. The visual size of the source.
3. The brightness level to which the eyes are adapted.
4. The position of the source in the visual field.

Certain other factors have important modifying influences upon the basic factors and include:

1. The number of sources in the visual field.
2. The configuration of the sources.
3. The criticalness of the visual tasks being performed.

This paper is a summary of a series of investigations which illustrate the relative influence of each of the basic factors upon comfort and discomfort.

EXPERIMENTAL ENVIRONMENT

The attainment of as complete control as possible of all the environmental conditions is an important consideration of any subjective type of investigation. Unless this is accomplished, extraneous factors may exert undue influence upon the observer whose appraisal may be of these factors rather than of the variable being studied. Therefore, considerable care was exercised in establishing an experimental environment, in determining a criterion, and in developing a technique. Since these are adequately described elsewhere,[2] only a brief summary is presented here.

The experimental environment used in these investigations involved a series of limited luminous areas which could be superimposed upon an extended visual field of uniform brightness. For most of the phases of these investigations these conditions were obtained in an 80-inch photometric sphere, one-third of which was cut away as is illustrated in Figure 1. The observer's head was positioned in a headrest so as to locate his eyes at the center of the sphere which occupied the entire unrestricted visual field. A lamp located immediately above the head of the observer provided the uniform brightness of the visual field. A small shield immediately under the lamp eliminated any sensation of heat or brightness from above.

Light sources mounted behind circular openings in the surface of the sphere provided the sources of brightness which the observers were required to adjust so that they induced the desired sensation. By using

appropriate filters in front of the light sources, it was possible to obtain apparent constancy of color of the sources for a relatively large change in voltage. Thus, by the proper combination of lamp and color correcting filter, a reasonably constant spectral quality was maintained over the range of brightnesses from zero to about 30,000 footlamberts. This minimized the possibility of the color of the source influencing the judgment of the observers. Those sources which were not used during any particular part of the investigation were adjusted to equal the field brightness and became indistinguishable from it.

CRITERION

Since comfort and discomfort are sensations, their appraisal can be made only by those who experience such sensations. Thus, it is necessary to develop a subjective technique and a criterion which will be reliable and consistent. Different individuals may vary considerably in their appraisals but the trends are decisive. It is possible for two or three observers to agree upon a series of definitions of various degrees of comfort or discomfort. However, any particular sensation would be a matter of considerable debate among a large group of individuals. Therefore, the most suitable criterion should be confined to a single sensation which could be defined by the experimenter and which could be interpreted by the observer as a relatively definite sensation. Furthermore, it was desirable to establish a criterion which would be meaningful from a practical viewpoint. It was decided that a threshold or borderline criterion would be most satisfactory. The one which appeared to fulfill these primary requisites was the *sensation at the borderline between comfort and discomfort*. This is termed the BCD sensation. This sensation was considered appropriate for the visual situation which involved casual or noncritical seeing, since under these conditions the observer is able to devote his entire attention to the evaluation of the source of brightness.

TECHNIQUE

The technique used for appraising the brightnesses of sources was similar to that developed by Luckiesh and Holladay[1] but was modified in accordance with later experience and knowledge. The observer was required to evaluate the sensation of brightness when a source was exposed to view amid the surrounding field of uniform brightness. An exploratory investigation of momentary and prolonged exposures indicated that both methods gave the same results for the sensation at the borderline between comfort and discomfort. This has since been established more definitely.[3] However, the observers expressed a feeling of greater confidence in their ability to arrive at the desired appraisal with

the momentary exposure of the source which was decided upon as the technique to be used. This condition approximates that of a worker looking up from the adaptation brightness of his work area, such as a task, toward a source of higher brightness and evaluating the sensation received during the initial period that the source was viewed. Furthermore, the short exposures permitted the maintenance of the adaptation brightness level as close to that of the surrounding field as possible. However, the exposure time was sufficiently long for the observer to receive and to experience the full sensation from the source of brightness. Considerable experimentation guided in the standardization of 1-second exposures separated by 1-second intervals during which the observers were exposed to only the field brightness. A 10-second cycle was devised during which the sources were presented for a subjective evaluation three times, and during the remaining brief period the observer was allowed to adjust the brightness of the test source.

An absolute method was devised for determining the average brightness at the borderline between comfort and discomfort when the test source was located on the line of vision. This method involved three 1-second "on" periods separated by 1-second "off" periods and followed by a 5-second "off" period during which the observer could resolve the sensations received during the "on" periods and alter the brightness of the test source for the next appraisal cycle.

When the test source being evaluated was displaced from the line of vision, it was possible to locate a standard or comparison source on the line of vision. Thus, the sensation induced by the test source T could be compared with that induced by the comparison source C which was set at a pre-determined brightness by the experimenter. The brightness of the test source was adjusted by the observer until the sensation received from it was the same as the initial sensation received from the comparison source. During a 10-second cycle the sources were exposed alternately for 1-second periods with 1-second intervals and a 5-second "off" period for evaluating the sensation of brightness and for altering the brightness of the test source. Thus, in any one cycle, the exposure of one of the sources was preceded and followed by the exposure of the other source. During two successive 10-second cycles, the order of presentation of the two sources was reversed.

The influence of the experimenter was minimized to the greatest possible extent. After adequate explanation of the procedure, the observer was left alone to arrive at his conclusion at each step in the investigation. He was always permitted as many exposure cycles as he deemed necessary to make a considered appraisal. A series of five apprai-

sals was made by each observer for each combination of experimental conditions on each of two days.

STANDARD BCD BRIGHTNESS

Since definite relationships are indicated among the various factors which determine whether sources of brightness are comfortable or uncomfortable, it was decided to first establish a meaningful brightness for standardized conditions. This, then, would be a value that could be used as a common denominator for relating all the variables. The standard test conditions were obtained in the sphere illustrated in Figure 1 and included a circular source (1.48 inches in diameter), located on

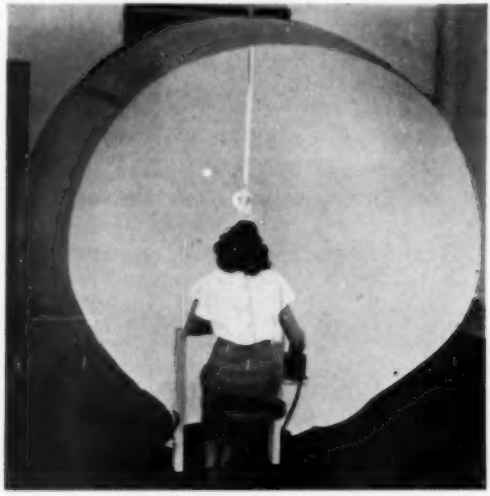

Fig. 1. The experimental environment used in most of the investigations was the illuminated white inner surface of an 80-inch sphere at the center of which the observer's eyes were located. This unrestricted surrounding visual field was illuminated by a lamp located above the head of the observer. The brightness of the test-sources, which consist of circular apertures in the spherical surface, is adjusted by the control under the observer's right hand. The photograph illustrates the brief period during which a test-source located 20 degrees above the line of vision was exposed.

the line of vision, and viewed amid a surrounding field brightness of 10 footlamberts. At the viewing distance of 40 inches, the circular source subtended a solid angle of 0.0011 steradian. The absolute method was used for determining the standard BCD brightness. That is, the source was viewed directly by the observers who adjusted its brightness until it was judged to induce a sensation at the borderline

between comfort and discomfort or the BCD sensation.

In order for the standard BCD brightness to be representative, a random group of 50 observers was used in this phase of the investigation. The average BCD brightness for each of the observers is presented in Table I. It is seen that the individual values range from 315 to 1600 footlamberts and that the geometric mean BCD brightness is 830 footlamberts. The variation among the individual observers is to be expected because of the many physiological and psychological factors which may influence the subjective appraisal of bright areas. Contrast sensitivity, for example, has been demonstrated to vary widely for a group of observers who may be otherwise rated equal, and are so-called normal, on a visual acuity basis.[4] Furthermore, standards of comfort or discomfort vary greatly among individuals.

TABLE I

The BCD brightness in footlamberts of the standard circular source (subtending 0.0011 steradian) located on the line of vision which produced an initial momentary sensation as judged by each of 50 different observers to be at the borderline between comfort and discomfort. The field brightness was 10 footlamberts. Those indicated by an asterisk participated in subsequent phases of the investigation.

Observer	Brightness	Observer	Brightness
*1	410	26	1040
*2	820	27	910
*3	1040	28	1530
*4	880	29	1300
*5	910	30	670
6	1170	31	990
7	580	32	850
*8	910	33	1380
9	1300	34	625
*10	885	35	405
*11	1600	36	630
*12	450	37	950
*13	1060	38	810
14	1530	39	1440
15	930	40	810
16	370	41	985
17	445	42	640
18	400	43	650
19	750	44	470
20	990	45	1230
21	860	46	820
22	1170	47	980
23	955	48	1080
24	1000	49	840
25	315	50	770
		Geometric Mean	830

An analysis of these data indicates that an approximately normal distribution was obtained from the 50 observers. Thus, the group as a whole and the mean value of BCD brightness are representative of a

much larger group. The geometric mean is used since it is less affected by extreme values than is the arithmetic mean. Hence, it is a more typical average especially when there is a relatively wide spread of the data. The 10 observers indicated by asterisks were selected as being representative of the 50 observers and were used in the subsequent phases of the investigation.

A comparison between the average BCD brightness obtained in this investigation with the value obtained by applying the so-called Holladay formula[1]

$$K - 0.022 = \log B + 0.25 \log Q - 0.3 \log F \qquad (1)$$

shows a striking agreement.* In this the magnitude K of the initial sensation produced by a source of brightness is expressed as a function of its brightness B and solid angle Q and the adapting field brightness F. Luckiesh and Holladay determined the value of K to be 1.9 when the sensation was at the boundary between comfort and discomfort which corresponds to the BCD sensation. Substituting the standard experimental values ($F = 10$ footlamberts, $Q = 0.0011$ steradian, and $K = 1.9$) in the formula, the calculated brightness is 827 footlamberts as compared with the mean value of 830 footlamberts found in the present study. Thus, the two groups of observers, under similar test conditions, appraised the same brightness as being at the borderline between comfort and discomfort.

SIZE OF SOURCE

Five circular sources, ranging in size from 0.46 inch to 16 inches, were used for determining the effect of size upon the BCD brightness. At the viewing distance of 40 inches these sources subtended solid angles from 0.0001 to 0.126 steradian. The physical data pertaining to the sources and the average BCD brightnesses as determined by the representative group of observers for a field brightness of 10 footlamberts are summarized in Table II. The relationship between these BCD brightnesses B and the solid angle Q (steradians) are plotted in Figure 2. This relationship approximates a linear logarithmic one for a range of Q from 0.0001 to 0.01 steradian. However, the BCD brightness decreases more rapidly for larger sources, from 0.01 to 0.13 steradian, than for smaller sources. The straight line portion of the curve includes the range of sizes used by Holladay, who also found a straight line relationship. The entire range of data may be represented by the empirical formula

$$B = 296Q^{-0.21} - 377. \qquad (2)$$

*The Holladay formula has been modified by incorporating the subtractive factor (0.022) so that brightnesses may be expressed in footlamberts.

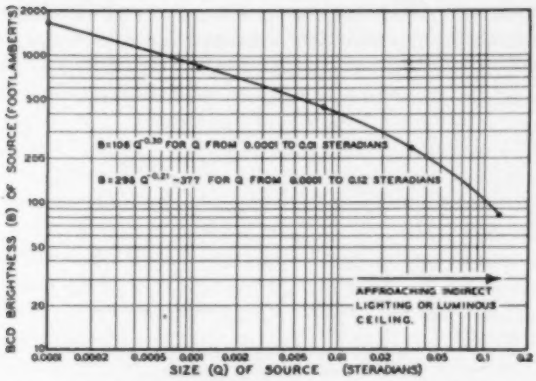

Fig. 2. The relationship between BCD brightness B and size Q of sources located on the line of vision for a surrounding field brightness F of 10 footlamberts.

The exponent of Q is in general agreement with Holladay's who found that a value of 0.25 gave a good approximation for the range he studied.

TABLE II

Dimensions of the circular sources and the average BCD brightnesses in footlamberts of these sources, located on the line of vision which produced an initial momentary sensation judged to be at the borderline between comfort and discomfort. The field brightness was 10 footlamberts.

Size of source, steradians	0.0001	0.0011	0.0079	0.0314	0.126
Visual angle, degrees	0.66	2.12	5.72	11.42	22.62
Diameter, inches	0.46	1.48	4.0	8.0	16.0
Area, square inches	0.167	1.72	12.6	50.3	201
BCD Brightness, footlamberts	1660	830	447	237	82

From Figure 2 it can be seen that the relationship between BCD brightness and size of sources is a variable one. Thus, a change in one factor required as a result of an increase or decrease in the other factor is dependent upon the absolute values of size and brightness that are involved. For example, when the size Q of the source is less than 0.01 steradian, doubling its brightness requires that it be reduced to about one-tenth of its original size. As the size of the source is increased progressively above 0.01 steradian, doubling its brightness requires progressively less of a reduction in size.

FIELD BRIGHTNESS

The field or adaptation brightness is an important factor which influences the sensation induced by a source of brightness. In this part of the experiment the size of the source located on the line of vision

was constant at 0.0011 steradian. The average BCD brightnesses as determined by the representative observers for field brightnesses of 1, 10 and 100 footlamberts were found to be 302, 830 and 2,325 foot-

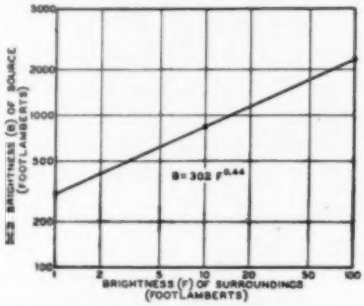

Fig. 3. The relationship between BCD brightness B of a source, located on the line of vision and subtending a solid angle of 0.0011 steradian, and the surrounding field brightness F.

lamberts, respectively. These values are plotted in Figure 3 and may be represented by the equation

$$B = 302F^{0.44} \qquad (3)$$

where B is the BCD brightness of the source and F is the field (adaptation) brightness.

The straight line relationship agrees with that found by Luckiesh and Holladay[1] and by Nutting.[5] The coefficient of F as determined by these earlier investigators was higher primarily because the criterion used by them involved the sensation of glare. In this study the sensation was the borderline between comfort and discomfort which is defined as being less than the sensation of glare in its usual meaning. Holladay found that the exponent was somewhere between 0.15 and 0.4 with a probable average value of 0.3. The value determined by the present work is 0.44 which is approximately the same as Holladay's upper limit. The difference probably is due to slightly different experimental situations and to the differences between the observers used in the two investigations. It is believed that the larger group of observers used in the present investigation is more nearly representative of the average than that used in the earlier work.

POSITION OF SOURCE IN VISUAL FIELD

One of the most important among the factors which have an effect upon the visual sensation induced by a source of brightness is the position of the source in the visual field. While the sources in a lighting installation often may be viewed directly, in the usual situa-

tion they are located at an appreciable angular distance from the normal line of vision. Thus, it is necessary to have quantitative data regarding the effect that the position of the source has upon the brightness which will induce a sensation at the borderline between comfort and discomfort or a BCD sensation.

A series of circular sources of brightness was located at various angular distances from the line of vision along the vertical, diagonal and horizontal meridians of the sphere. The 1.48-inch diameter sources subtended solid angles of 0.0011 steradian at the viewing distance of 40 inches. Since the sources were located on the inner surface of the sphere, they were of a constant visual size and shape. The comparison method was used for determining the BCD brightnesses of the sources as they were positioned at various angular distances from the line of vision. The central or comparison source, located on the line of vision, was set at the standard BCD brightness of 830 footlamberts determined in the basic phase of the investigation. The brightness of the surrounding field was maintained at 10 footlamberts. Since the comparison source was at the BCD brightness, and the off axis sources were adjusted by the observers to produce the same visual sensation, the latter are also BCD brightnesses.

The average BCD brightnesses as determined by the representative group of 10 observers are summarized in Table III. The angular displacement of the sources was extended to cover the limits of the visual fields for all observers. Thus, all of the observers were able to see a source located 50 degrees above the line of vision, but only four were

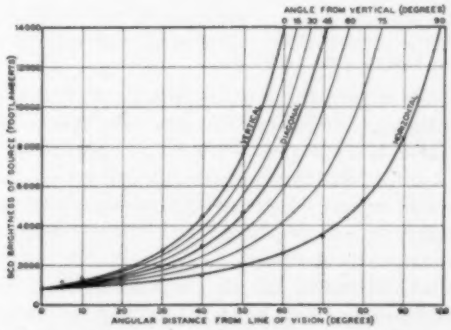

Fig. 4. Illustrating how the BCD brightness increases as a circular source, subtending a solid angle of 0.0011 steradian, is displaced along various meridians from the line of vision. The heavy lines represent observed data for vertical, diagonal and horizontal displacement. The thinner lines for the intermediate meridians have been interpolated. These data were obtained when the field brightness was 10 footlamberts.

able to see the source of 60 degrees. These latter data were used for extrapolating the average curve to 60 degrees. Similarly, sources displaced 70 degrees diagonally and 100 degrees horizontally were outside the visual field for some of the observers.

The manner in which the BCD brightnesses increase as a source is displaced from the line of vision is presented graphically in Figure 4. The heavy lines representing vertical, diagonal and horizontal displacements are smooth curves drawn through the average observed values. The thinner lines for the intermediate meridians have been interpolated. From these curves it is seen that a specific source of brightness is more effective in producing a given sensation when displaced horizontally from the line of vision than when it is displaced the same angular

TABLE III

BCD brightnesses in footlamberts of circular sources (subtending 0.0011 steradian) located at various angles (θ) from the horizontal line of vision. The field brightness was 10 footlamberts.

Angle θ from line of vision in degrees	BCD Brightness in Footlamberts		
	Vertical	Diagonal	Horizontal
0	830	830	830
5	1165	1020	886
10	1344	1051	928
20	1764	1338	1037
30	2764	1967	1254
40	4452	2937	1463
50	7615	4500	2015
60	14000*	7658	2566
70	------	13500*	3423
80	------	------	5212
90	------	------	8396
100	------	------	15000*

*Outside of visual field for some observers.

distance vertically above the line of vision. For example, a source having a brightness of 2,000 footlamberts must be displaced 50 degrees horizontally but only 23 degrees vertically in order to be at the borderline between comfort and discomfort. Or, stated in another way, a 2,000-footlambert source displaced 50 degrees horizontally and a 7,600-footlambert source displaced vertically are both BCD brightnesses for the standard conditions.

A graphical illustration of the variation of BCD brightnesses of the circular sources located in the visual field above the horizontal line of vision is presented in Figure 5 when the point of fixation is at zero degrees. The heavy solid curved lines represent iso-BCD brightnesses or lines of equal BCD brightness. A striking point is the similarity between the shape of the BCD curves and a curve representing the

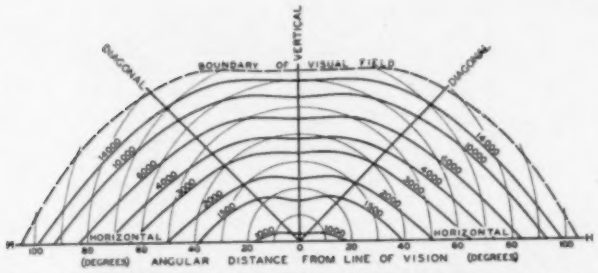

Fig. 5. A graphical illustration of the variation of BCD brightnesses of circular sources (subtending 0.0011 steradian) located in the visual field above the horizontal. The point of fixation was at zero degrees and the brightness of the field was 10 footlamberts. The heavy solid curved lines represent points of equal BCD brightness. The broken curve represents the boundary of the visual field.

boundary of the binocular visual field. The latter dotted curve is based upon data published by Duke-Elder and Sheard.[6] The slight dip in the curves along the vertical meridian is real and also appears to follow the shape of the boundary of the visual field.

COMBINED RELATIONSHIPS

When the relationships between the average BCD brightness B of a source, the size of source Q and the field brightness F are combined in a single expression, the following empirical formula is obtained from Equations (2) and (3)

$$B = 108F^{0.44}(Q^{-0.21} - 1.28). \qquad (4)$$

This is plotted in Figure 6 for three values of field brightness. The solid dots indicate the points for which complete experimental data have been obtained. Dotted lines have been drawn parallel to the 10-footlambert curve for field brightnesses of 1 to 100 footlamberts. Sufficient data were obtained for the smallest and largest sources to check the parallel relationship which was previously found by Holladay.

Figure 6 and Equation (4) pertain to a source located on the line of vision. In other words, it is assumed that the source is viewed directly by an observer. Furthermore, it is emphasized that the BCD brightnesses are *average* values and merely mean that *half* of any given group can be expected to find the sensation of brightness from a source to be at, or more comfortable than, the borderline between comfort and discomfort. Nevertheless, the average value is a useful one for the purpose of establishing the relationships among the various governing factors.

Since sources often are not viewed directly, it is desirable to incorporate in Equation (4) an additional factor which would represent

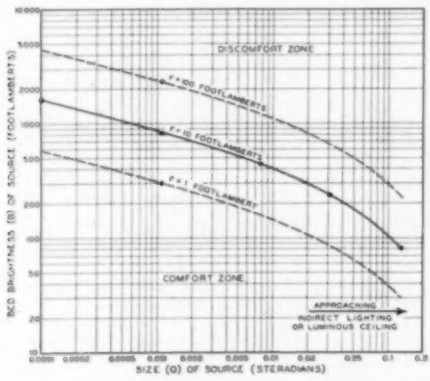

Fig. 6. The relationship between BCD brightness B and size Q of sources located on the line of vision for three surrounding field brightnesses F.

the permissible increase in source brightness as the source is moved from the line of vision. This factor, which can be in terms of the relative BCD brightness of a source located anywhere in the visual field, can be obtained from either Figure 4 or Figure 5. However, on these charts, the source is considered to be on the surface of a sphere which necessitates the determination of the angle of a meridian from the vertical and the angular position of the source along this meridian. It would be simpler to be able to define the position of a source in terms of its linear displacement from the eyes of the observer. Thus, a source can be considered to be located in a vertical plane normal to the horizontal line of vision. The position of the source then may be specified by a vertical distance V above, and a lateral distance L to one side of, the point where the horizontal line of vision intersects the vertical plane. By expressing these distances in terms of the distance R from the eyes to the vertical plane, the numerical ratios $\frac{V}{R}$ and $\frac{L}{R}$ become simple factors for determining a *position index P*. If the position index P is in terms of relative BCD brightnesses, a diagram such as that shown in Figure 7 may be used to determine the BCD brightness of a source located anywhere in the visual field above the line of vision. Figures 5 and 7 are similar except that linear measurements are involved in the latter.

The position index P indicates the relative BCD brightness of a source displaced from the line of vision in terms of the BCD brightness of a source located on the line of vision. Thus, if the BCD brightness of a specific source on the line of vision is B footlamberts, the

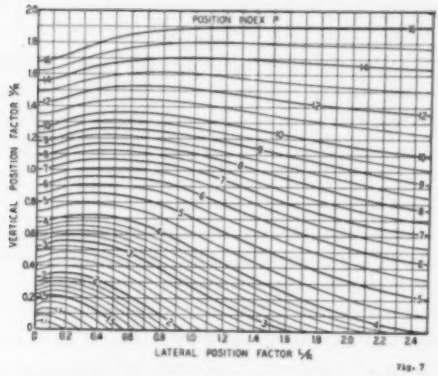

Fig. 7. Chart for determining the Position Index P, in terms of relative BCD brightness, of sources located at various positions in the visual field. V and L are the vertical and lateral distances, respectively, from the line of vision and R is the distance from the eye to the vertical plane normal to the line of vision in which the source is located.

permissible BCD brightness will be BP footlamberts when the same source is displaced from the line of vision. Equation (4) becomes

$$B = 108PF^{0.44}(Q^{-0.21} - 1.28). \quad (5)$$

Equation (5) may be rewritten as

$$M = \frac{B}{PF^{0.44}(Q^{-0.21} - 1.28).} \quad (6)$$

where M represents an index of sensation of visual comfort when a source is exposed to view. When M is equal to 108 (as in Equation 5) the combination of source brightness B, size Q and field brightness F is such that the initial sensation of brightness received from the source is at the borderline between comfort and discomfort or BCD for the average observer. Smaller and larger values of M indicate greater comfort or discomfort, respectively. An analysis of the data obtained with the 50 observers in the initial phase of this series of investigations indicates that a brightness corresponding to approximately one-half the average BCD value can be expected to be comfortable for about 90 per cent of those who may view the source. In Equation (5) this would mean that the value of M should be 55 instead of the average value of 108. Stated in another way, the lower value of M would indicate that the visual sensation induced by the source of brightness would be less than BCD for the average observer who probably would find it not uncomfortable. Equation (5) may be used for determining the average BCD brightness of a source and Equation (6) is useful for determining

the numerical rating for the sensation that a source may be expected to induce.

It is emphasized that the relationships given in Equations (5) and (6) hold only for the range of the experimental data and cannot be extrapolated for larger sizes of sources without obtaining BCD values which are without meaning. For example, when the field brightness is 10 footlamberts and the source is located on the line of vision ($P = 1$), if Equation (5) were extended in range to a source subtending a solid angle of about 0.32 steradian, the BCD brightness would become zero and for larger sources would be a negative quantity. Obviously this is an empirical equation of limited range. Nevertheless, the results do indicate that large expanses of luminous areas become uncomfortable even when their brightnesses are relatively low.

From these relationships it is possible to determine how increasing or decreasing the value of one of the factors influences the BCD sensation and how the other factors must be varied to compensate for a change in one. Thus, if the brightness of a specific source is doubled, the sensation may be maintained at BCD by an appropriate reduction in size of source, increase in field brightness, or greater displacement of the source from the line of vision. However, the actual changes in size and field brightness are dependent upon the absolute values of source brightness and size that are involved. For example, for a given BCD brightness of a source when the size of the source is 0.001 steradian, the area of the source may be increased about 2.6 times, or to 0.0026 steradian, if the field brightness is doubled. However, when the size of the source is as large as 0.1 steradian, its area may be increased by a factor of only 1.3, or to 0.13 steradian, when the field brightness is doubled. Similarly, changing the position of the source may be compensatory. Doubling the brightness requires a doubling of the position index P. Figure 6 illustrates the variations in $\frac{L}{R}$ and $\frac{V}{R}$ when, for example, P is increased from 2 to 4. This is also shown in Figure 5 except that angular measurement is involved.

From the foregoing it is evident that when the brightnesses of sources are increased, considerable care must be exercised to make necessary compensating increases in the field brightness, decrease in the size of the source, or increase in its angular distance from the line of vision, or all three.

The development of Equations (5) and (6) includes all the factors which can be conveniently incorporated in a single expression.

The modifying factors such as the number of sources in the visual field and the criticalness of the visual task can more easily be introduced in a general concept or method of applying the empirical relationships. Space prevents a presentation of the manner in which these other factors influence the sensation which will be received from sources of brightness. However, they are described in detail elsewhere.[2, 3]

SUMMARY

The foregoing is a summary of an extensive series of investigations dealing with the complex relationships among certain of the factors which govern whether sources of brightness are comfortable or uncomfortable. The factors of size, brightness, and position of the source, and the adaptation brightness have been combined in an empirical formula which makes possible the determination of the conditions which should be expected to produce a comfortable or uncomfortable visual sensation.

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ABSTRACTS

FACTORS INFLUENCING THE POSTOPERATIVE RESULTS IN CONCOMITANT CONVERGENT STRABISMUS. J. H. Dunnington and E. F. Regan. Arch. Ophth., *44*, 813-822. December, 1950.

Of 79 cases of concomitant convergent strabismus that were followed for at least seven years after operation, 56 per cent showed less than 10Δ deviation. Several observations are given as to the probable causes of failure. Most poor results seemed to have been produced by injudicious selection or by postoperative adhesions.

Low vision in the squinting eye seemed to increase the likelihood of postoperative divergence and the presence of 4 D., or more, of hyperopia seemed to increase the tendency to secondary divergence. The refractive error, visual acuity, near point of convergence, ocular dominance, and the movements of the eyes in the different directions of gaze are important preoperative considerations. However, it is interesting to note that the authors found that abnormal retinal correspondence is not a contra-indication to operation.

R. E. B.

THE SIGNIFICANCE OF SNELLEN ACUITY IN UNCORRECTED MYOPIA*

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The relationship between uncorrected visual acuity measured with Snellen letters and the degree of ametropia has always interested refractionists. It is the object of this study to investigate this relationship and also to determine if whatever relationship exists may be used as a guide to the refractive error. This is not an experimental study but rather a statistical compilation made from the case records of an optometric practice.

PREVIOUS STUDIES

Several previous investigators have attempted to correlate visual acuities and corresponding degrees of myopia. Their results are tabulated in Chart 1. In most cases, the variability of their results is given only passing mention, if any at all. Each of these previous studies was done on a small, selected group of patients who were usually of similar age, sex, and vocation. The test conditions varied greatly in the various investigations, and, therefore, the results are not strictly comparable. Thorington, for example, measured the visual acuity while the patient was under cycloplegic, and his subjects included hyperopes as well as myopes and astigmats wearing cylindrical corrections. He does not mention the drug used or the number of cases included, but does suggest the use of his results as a refractive aid. His chart was calibrated in the metric system, but nevertheless his values fit the equation $E = 2.5\ [1\text{-}s]$ where s is the Snellen fraction and E the expected spherical correction. Kempf and his colleagues used the retinoscopic findings on 123 school children as measures of the refraction. However, these investigators included simple and compound myopic astigmatism along with simple myopia in their data without any differentiation. Agatson simulated myopia by adding plus spheres to the corrections of six normal individuals. This method eliminates the influence of any possible adaptation of the myope to his environment. The subjects employed by Crawford and his associates, as well as those of Eggers, were military personnel, all young males. Crawford's results are mean values from 392 cases. His chart did not contain a 20/300 letter. Eggers' results

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†Optometrists.

CHART 1
Visual Acuity For Various Refractive Errors As Found By Previous Investigators

Error of Refraction (in diopters)	VISUAL ACUITY*				
	Agatson	Crawford	Eggers	Hirsch	Thorington
0.25		20.6			22.2
0.50	30	34.5	30	25	25
0.75		44.4	40		28.5
1.00	50	53	50	65	33.3
1.25		60	70		40
1.50	70	91	100	110	50
1.75		145			66.6
2.00	100		150	165	100
2.25					200
2.50	200	200	200	215	
2.75					
3.00	300	400	250	285	
3.25					
3.50	400		300	350	

*The acuities given in the above table are expressed as the denominators of the Snellen fraction found by each investigator for each degree of myopia.

are what he terms "deductions" from his data which contained about 300 cases. Hirsch alone of all these investigators dealt also with the problem of distribution. However, he was limited by the fact that he tested only 64 eyes, and that some of these were wearing the spherical equivalent of their true prescription. His subjects were college students. He found that when visual acuity and refractive error were related logarithmically (the log of the Snellen fraction against the log of the error), his data fall onto a more or less straight line. To obtain distribution values, Hirsch assumed that, in terms of these coefficients, there would be a normal distribution for each degree of myopia.

PRESENT STUDY

The great bulk of the data in this study was obtained by two optometrists working under very similar conditions in two different refracting rooms. The testing distance in each case was 10 feet and the Snellen letters were projected onto a screen by means of an American Optical Company projecto-chart equipped with a B tube. The slides used contained letters of 15 sizes ranging in size from 20/400 down to 20/10. The rooms were semi-darkened during the measurements while lamps on the instrument stands provided additional diffuse illumination. The patients were cautioned against squinting. The patients were of all ages, and of varied educational and vocational backgrounds. Virtually all resided in the metropolitan New York area. There are 1,105 simple myopic eyes, of no more than 3.50 diopters error, in this study.

approximately equally divided between males and females. The data were gathered over a period of years. In each case the value chosen as the measure of the refractive error was the distance subjective correction derived by the fogging technique. All cases which could not be restored to normal acuity were excluded.

FACTORS INFLUENCING VISUAL ACUITY

After considering the myriad of factors which influence the visual acuity of an individual, a great deal of variation is to be expected in any study such as this in which only the refractive error and the test conditions are constants. According to Ludvigh, the resolving power of the ametropic eye is primarily dependent upon the gradient of retinal illumination; that is, on the contrast within the blurred image. The more diffuse the light distribution, the more seriously affected will the visual acuity be. Relatively poorer acuities are to be expected therefore in those patients with large pupils or axial myopias since these are conditions in which the blurred image is enlarged.

Individuals will also differ in their innate resolving ability. A certain percentage of patients in any group are correctible to 20/15 while some others are correctible only to 20/25. This fact may be accounted for by differences in the positioning of the optical media of the eye, or their condition, the topography of the foveal pit and retina, the dimensions of the cones, variations in the aberrations of the eye, fixation ability, the state of maturation, and the physiological nystagmoid movements. Some factors, such as the state of adaptation, the extent of the tear film, the discharge frequency, the immediate diet, fatigue, and motivation, have varying effects on individual subjects depending upon the time the tests are made and therefore will cause variations in the individual's visual acuity from time to time.

To these factors we must add the important influence of certain psychological conditions. Patients will differ in their familiarity with letters, the proportion of the day their correction is worn and also the length of time they have been wearing a correction, intelligence, temperament, power of attention, and in their reaction to the attitude of the examiner. Most of these psychological factors are impossible to adequately control as are many of the physiological factors cited above.

RESULTS

It is apparent from our results that visual acuity alone, as measured by the Snellen technique, can hardly be considered a significant guide to the ametropia in an individual case. Our data contain, for example, individuals who at best could read the 20/60 line uncorrected and were

found to require corrections anywhere from —0.50 to —3.00 D. It is possible, of course, to draw up a list of norms or expecteds, based for instance on the medians listed in Chart 2, but these would have to be considered as rather flexible. In our results, no category below 3.00 D.

CHART 2

RESULTS OF PRESENT INVESTIGATION

Degree of Myopia (in diopters)	Number of cases	Mean *	Median *	Per cent of cases at median	Approximately 50% of cases * #	Quartile Deviation *
0.25	105	27	25	39	20 to 30	5
0.50	146	35	30	36.3	25 to 40	7.5
0.75	130	43	40	28.4	30 to 60	15
1.00	147	77	60	13.5	50 to 80	15
1.25	118	102	80	11.1	60 to 100	20
1.50	104	144	100	15.4	70 to 200	65
1.75	64	185	200	42.2	100 to 200	50
2.00	103	226	200	46.6	200 to 300	50
2.25	44	231	200	43.2	200 to 300	50
2.50	40	292	300	12.5	200 to 400	100
2.75	30	307	300	13.2	200 to 400	100
3.00	31	299	300	25.5	200 to 400	100
3.25	21	350	400	54.8	400	50
3.50	14	329	400	64.3	400	50

*The acuities given in the table are expressed as the denominator of the Snellen faction.
#This column gives the visual acuities which are the lowest and highest acuities for the middle 50 per cent of the cases.

has as many as one-half the cases at any one acuity reading. Visual acuities for the higher errors tend to be more grouped than those for the smaller errors, but this is largely due to the greater separation of the higher acuity lines on the chart. As a matter of fact, it is probably these higher errors which are more variable. For example, 35 per cent of the 2.50 D. myopes could resolve a letter twice as small as the median for the group. This was true of only 11 per cent of the 1.50 D. myopes and 1.5 per cent of the 0.75 D. myopes.

We would normally not expect the 2.50 D. myope, who probably wears his correction almost constantly, to be better at blur circle interpretation than the 0.75 D. myope who is much less likely to wear his correction constantly. The explanation for this may lie, however, in the optics of the situation. While the 20/20 letter is half the angular size of the 20/40 letter just as the 20/50 letter is half the angular size of the 20/100 letter, it may be an easier task in blur interpretation to make out a letter half the size of the larger letters than a letter half the size of one nearest the ultimate in retinal capacity.

CONCLUSIONS

The Snellen acuity test as it is generally administered is not an accurate indication of the degree of myopia. Higher degrees of myopia are undoubtedly associated with poorer visual acuities than lower errors, but under standard clinical conditions there is much overlapping from error to error. If any attempt is to be made to use visual acuity diagnostically, the more important variables should be kept constant. The relationship between myopia and visual acuity, as well as the variability of that relationship, have been presented in our data. No significant differences between males and females were found with regard to any phase of the statistical results. Our findings indicate that for those subjects with the higher degrees of ametropia, the conventional Snellen test is least consistent. However, this is compensated for by the poor selection of letter sizes provided beyond 20/100. The susceptibility of visual acuity to factors other than the refractive error is suggested by the difference recorded among individuals whose eyes have identical ametropias.

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OPTOMETRIC PUBLIC RELATIONS AS VIEWED BY A COLLEGE DEAN*†

At a recent meeting of the Association of Schools and Colleges of Optometry this speaker was assigned a subject to present before that group. It was to concern itself with optometric public relations. The

*Read before the annual meeting of the American Academy of Optometry, December 17, 1950. For publication in the September, 1951, issue of the AMERICAN JOURNAL OF OPTOMETRY AND ARCHIVES OF AMERICAN ACADEMY OF OPTOMETRY.

†Richard Feinberg, Ph.D., Dean, Northern Illinois College of Optometry, Chicago, Illinois. Fellow, American Academy of Optometry.

material was delivered as requested and the response to it lead to the presentation of this paper.

The author is not a public relations specialist. His experience, however, encompasses being the first executive secretary of the New York State Optometric Association's Public Health Bureau, which later was moved to Pittsburgh, and under the excellent direction of Dr. Elmer Soles became the Public Relations office of the American Optometric Association. During those crusading days he worked closely with Dr. William Feinbloom who spear-headed optometric public relations, and with a host of colleagues who had confidence that with the correct approaches to the public and to the other professions, optometry would find its rightful place in the sun. That this hope is now being realized is explicit. The speaker has been in private practice, has worked with governmental agencies, has spent several full years in heading up an industrial vision program, has spent years in the academic world, and now enjoys the position of Dean of the College of Optometry at Pacific University.† By sheer exposure to these varied and intensive activities it would be impossible to avoid the formation of some patterns of thinking in regard to optometry's present and future relations with fellow professions and with the public.

An approach to our subject might be made facetiously through a "visual analysis" technique. Let us examine the case history. Our patient states that she is legally approximately 30 years of age in Texas. We suspect that she is really a great deal older and find that she is recorded as being 50 years of age in Minnesota. It has been only within the last decade that she has become aware of a visual near-point problem and, in that same period, has been confronted with occupational seeing demands. With the advent of World War II, and since, she has found that she could make a real contribution in the factory. Her children have given her new concern regarding their sight development in the pre-school and school years and she finds herself preoccupied in this noble work, also. She has had an exacting emotional life. Her parentage has been questioned by her derogators and it has left some neurotic scars. Her street activities have not helped. In her earlier years she fought fiercely for her very existence, later, for her education, and later still, for suitable recognition. Finally, by sheer stint of self-drive, she has achieved some of her goals and now, somewhat self-satisfied, is inclined to settle down smugly and talk with her neighbors of the good old days. She is slightly myopic, yet complains of headaches. Her field is somewhat constricted but she has a history of autogenous toxemia. Her general physique is excellent. A summary of the visual analysis

†This manuscript was written at Pacific University.

would indicate that the patient, somewhat neurotic, needs reassurance, should be more informed as to the merits of visual training, and should become more exposed to social endeavors. The prognosis is more favorable.

I trust that you will pardon this indulgence in a bit of whimsy. It is often when we laugh at ourselves that we see ourselves best.

Given an optometry come-of-age and a public recognition of its merits, what else could be desired? Surely there is a little left wanting. Perhaps it is here that we shall begin our probing.

Whom do we attract to our profession? Why? What students do we admit? Are these not indices to one phase of our impact on the public?

What are our graduates doing upon entering practice? In what manner do they practice? How are they spurred on to that kind of practice that meets with the ideals of the American Academy of Optometry? What obstacles are there before them?

What creativity is there yet left for the optometrist? What new fields for exploration? What of our new responsibilities in the visual development of the child, in the occupational world, and in the military field?

What are we now doing to cement our relations with fellow professions? With the public? With what must our schools and colleges concern themselves so that our profession may survive and prosper? These are some questions we may ask ourselves.

The phrase "public relations" evokes in some a rather negative reaction since frequently it has been connoted to mean a kind of commercial extroverted behaviour. Actually the term implies communication with a general or a particular public. At work it is a process of developing ideas, initiating communication, obtaining attention and getting action. Public relations based upon a spurious commodity cannot live. It is true also, unfortunately, that without the public understanding and appreciation, some of the finest projects and endeavors have failed.

Evaluation of public relations is a continuous sampling procedure, for the task is never finished. When the momentum of a project or a profession is sufficiently established, the attitudes of the public are either pro- or con-. The state of indifference is passed.

The core of our professions has been a service which, in the majority of instances, involves use of prosthetic materials. We are linked with the commerce of spectacles in the same manner that a dentist is tied to the use of dental amalgams. As long as the service aspects of the

practitioner were secondary to the consideration of materials, the inevitable prevailed. The public regarded the optometrist primarily as an eye-wear dispenser and accorded him recognition commensurate with such business enterprise. The public never has been indifferent to optometry. It has been uninformed, perhaps, to many areas in which our profession could render valuable help, but so have our own practitioners. The public has been remarkably undisturbed by attacks upon optometry by its antagonists, for, basically, the public has made its own evaluation of the services rendered. Our wooing of fellow professions and agencies, both governmental and non-governmental, *has* suffered and only our intensive efforts to improve our education, to practice in a recognized professional manner, and to make a contribution to knowledge through optometric research, has assuaged the bitterness and has induced the opening of new doors to us.

There is then this two-fold reaction. On the one hand, there is the public seeking visual help. In the main, it has turned to optometry. On the other, there are large industries, the schools, the Army, the Navy, and other branches of the military who have taken a more critical position before seeking our assistance.

It has been necessary for us to recognize problems of which these particular publics have been ignorant, to identify these properly, to acquaint the specialized public with the nature of these problems, and then to have satisfactory solutions which were not prohibitive in cost or time.

We have had excellent assistance, sometimes almost in spite of ourselves. The large optical companies through their visual classification and screening programs have acquainted millions with the need for adequate vision at the work-point. The institutional advertisements stemming from these companies and appearing in our popular national magazines, likewise, have created a vision consciousness where none existed previously. Emphasis upon our profession has caused those who had regarded optometry as a commercial, if not fraudulent, cult, to look again. Upon closer inspection, their attitude was reversed and we now were countenanced with favor. We owe a great debt to those optical manufacturers who have championed us.

In the school world, recognition of reading comprehension as a clue to scholastic achievement has brought visual skills to the attention of the educators and they, in turn, now seek our help. This area of visual care is a new frontier.

There is little need to enumerate the specific seeing needs of the various groups occupied school-wise, industrially or militarily. You

are fully aware of these particular visual demands. My contribution in this paper is perhaps to state the modality by which we have arrived at this stage of optometric development and the means by which we shall continue to forge ahead.

There are two essential words to be placed before you as the key to our profession and to its continued progress. These are *integrity* and *prestige*.

Throughout optometry's entire existence, there has been a small group of men within the profession whose integrity never was questioned even by its toughest adversaries. This group was, almost principally, the membership of the American Academy of Optometry. On more than one occasion, the less deserving commercially-tinged optometrist sought protection behind the Academy's banner. I do not believe that the Academy has ever lent itself to an unworthy cause. Such a career is reflected in the prestige associated with this fine body of professional men. Christopher Edgar Persons in a manual of practical procedure of public relations for colleges and universities says of the word prestige:

"Prestige is a hard master. Its demands are ruthless, and its road is long and difficult. It cannot be ballyhooed or press-agented into existence, nor can it be long maintained where the conditions of it are not met. The efforts to circumvent its exactions are always before us, but they need not concern us. They are fool's gold. Its rewards are proportionate to its exactions. From true prestige all scholastic blessings flow. It maintains and provides faculty eminence, adequate facilities, and able students, because it provides the means for accomplishing these objectives. Take it away and nothing remains but the role of the beggar and the apologist or the blue-sky promoter. These roles are not usually successful in any enterprise."

These are memorable words to carry with us.

As the ranks of the older pioneers begin to thin, new men step into the lines. Perhaps they are trained more comprehensively for their profession but they will not surpass readily the idealism of the men who founded this profession. In our schools we must keep this fire alive.

Previously, in this paper, I posed a number of questions regarding our students and graduates. I should like to undertake now to answer some of them generally—all too briefly perhaps.

The quality of applicants we receive for consideration for entrance into our schools and colleges of optometry depends in great measure upon the quality of optometry practiced in the field as reflected in the mind of the public.

There is a profound difference between publicity and public relations. All the advertisements in the world denoting seven dollar glasses and free examinations by "registered optometrists" create nothing but contempt for a mercenary trade. On the other side, participation of our constituents in community activities and their quiet and efficient performance in a truly professional life will bring to the public an

unerasable respect. Our candidates for enrollment will multiply and our selection problems will be considerably lessened.

Our colleges can help to mold a professionalism through the graduates they develop. However, these men need assistance upon their entry into the professional world. Selfishness and bigotry as it exists in the ranks of some state boards must be eradicated. A helping hand rather than indifference or rejection on the part of the professional community will go far to encourage the kind of practice we desire.

In a very real sense the maturity of our profession will be measured by the caliber of research that it emanates. Our schools have a responsibility to encourage graduate work and research. We need *optometric* research performed by *optometric* personnel.

At the same time, every attempt to inflexibly crystallize our curricula and to make our schools identical must be resisted. Diversity is our scholastic strength and we should preserve the right for the schools to be different. This does not rule out basic standards; rather, it accentuates our particular contributions based upon our particular faculty interests and other facilities.

By placing ophthalmologists, illuminating engineers, safety engineers, psychologists, educators, and representatives of other professions on our school staffs, we are welding sound inter-professional relations. The schools that have brought inter-professional seminars into being have made another noteworthy contribution in this direction. Although the independent schools have awarded doctorate degrees in optometry to their graduates, Pacific University is the only university at present which presents such a degree. It is to be hoped that the other universities eventually will be able to do likewise, for the impact of this title upon the public is one which creates deserved respect. It removes forever the evasive apologists attitude of the optometrist who has been graduated with a bachelor degree and now finds himself called "doctor." It establishes among other professions an equal footing essential to us if we are all to work together.

Post-graduate training has largely been in the hands of the Optometric Extension Program which has established and maintained study groups over the United States. It would be remiss to pass the excellent work done by this Association without suitable acknowledgment. Reaching into the offices of the inadequately trained man, often the commercial man, the OEP has provided information and a new self respect which has done wonders for the whole of the profession. It has kept the optometrist abreast of new developments and theories. Regardless of what one's personal optometric philosophy may be, the good

that has been derived from this movement must be recognized.

In our colleges, graduate and postgraduate training are slowly but definitely coming into their own. Optometry majors are being encouraged to go on for advanced degrees in associated fields. One such highly trained man is worth a thousand "blue-sky promoters."

In our case history I stated that the prognosis of our patient is most favorable. Certainly, recent events have borne this out. The recent recognition by our medical confreres, military deferment of optometry students, active participation in the industrial vision area, all point to our coming of age. Particularly noticeable is the recent construction of optometric buildings on our campuses. Across the United States, our schools and colleges of optometry have been busily building bigger and better facilities for our student bodies.

In conclusion, we should face the fact that good public relations cannot be legislated. The vigilance of the American Optometric Association's legal staff is necessary, but, in itself, is powerless to act in creating good will on our behalf. The ideals of the American Academy of Optometry must continue to set the pattern by which optometry is to be practiced in this country. Through the portals of our schools come the next generation of optometrists and the generations of optometrists after them. What we impress upon our students must be supported by the actions of the optometrists serving the public. What these students will do when they in turn become practitioners will depend in large measure upon you. Our public relations must be founded upon our actions, not upon our words. *Integrity* shall be our banner.

RICHARD FEINBERG.

TRANSACTIONS OF THE AMERICAN ACADEMY OF OPTOMETRY

A department devoted to announcements, reports, appointments, organization data, news, professional problems and ideals, as these relate to the Academy.

ROOM RESERVATIONS FOR ANNUAL MEETING

NEW YORK CITY, DECEMBER 8-11, 1951

In less than 10 weeks, Academy members will be travelling to the East Coast for their first New York City meeting since 1935. This year, the headquarters will be in the Hotel New Yorker, and the meeting is scheduled for December 8, 9, 10 and 11. President Harold Simmerman advises that the Hotel New Yorker is now ready to accept room reservations and urges members to write immediately. The Academy hopes as many members as possible will take advantage of the excellent pro-

gram now being prepared by Dr. Meredith W. Morgan and his papers and program committee.

The four-day program will include approximately 30 technical papers, and as in the past, section meetings will be held covering aniseikonia, contact lenses, orthoptics, and this year for the first time, industrial vision. Pathology will be a topic for general sessions, along with the papers covering all phases of ocular refraction.

A special committee is now working on a list of restaurants New Yorkers feel the members will enjoy—the list will either be published or distributed at the registration desk. Obviously, there are many fine eating places to choose from—but all are not within easy access to the Hotel New Yorker, and the committee will try to choose those nearby.

For the fifth time in its 29-year history, the Academy will award an Honorary Life Fellowship to a man it feels has made many outstanding contributions to visual science. This year, Dr. William L. Benedict, ophthalmologist, Secretary of the American Academy of Ophthalmology and Otolaryngology, Editor of the TRANSACTIONS OF THE AMERICAN ACADEMY OF OPHTHALMOLOGY AND OTOLARYNGOLOGY, and former director of the Mayo Clinic's Section on Ophthalmology, Rochester, Minnesota, will be honored by a Life Fellowship. The award will be made at the annual round table banquet.

A full program of speakers and their topics will appear in the AMERICAN JOURNAL OF OPTOMETRY next month.

CURRENT COMMENTS

Virginia Huck
Editorial Assistant

Optometrists will confer a favor by sending news items of general interest for this department: such as relate to new instruments, clinical techniques, education, visual health and optometric legislation and organization.

INTERNATIONAL OPTICAL CONGRESS

We hope that members of the British Optical Association have been taking it easy these past few weeks enjoying the thought that their long-planned International Optical Congress was a tremendous successs and gave the hundreds who attended many pleasant memories as well as the feeling that international understanding in the profession had taken a long step forward.

The reports are all in now, and accounts of the educational programs, the luncheons, dinners, receptions and banquets sponsored by the Congress for their guests all praise the warm hospitality of the

hosts, the high caliber of technical papers, impressive exhibits and well planned sessions.

The Journal's special report comes from Dr. John C. Neill, Philadelphia, who represented the American Academy of Optometry and the Pennsylvania State College of Optometry at the Congress:

"I am now back in the U. S. after the most interesting three weeks in England, Scotland and France. It is difficult for me to know just where to begin the story of my visit. I arrived in London on Sunday morning, July 8th. Since the Congress did not officially open until Tuesday, I spent Sunday and Monday sightseeing. The Congress opened on Tuesday at 10 A. M. There were about 400 in attendance representing some 21 different countries. After the opening ceremonies, each country was called upon and the delegates arose and one of them extended greetings from his particular country.

"The following were the responses to the first roll call: Australia 6, Canada 1, Ceylon 1, Denmark 4, Egypt 2, Erie 1, Finland 3, France 3, Germany 12, Israeli 3, Italy 2, New Zealand 4, Netherlands 4, Norway 11, South Africa 1, Sweden 3, Switzerland 3, India 1, U. S. A. 3.

"The opening ceremonies with the address by Sir Harold Bartley, chairman of the Council of the British Society for the Advancement of Science, were very impressive. After lunch in the refectory of King's College the afternoon program got off to a prompt start with Lord Charnwood reading Bob Bannon's paper on aniseikonia. This was followed by Charnwood's own paper on retinal disparity. All questions were written out and after the speaker answered a question it was repeated in French and then in German by two different interpreters. Synopses of all papers were passed out before the paper was presented and these too were in English, French and German.

"Papers prepared by Louis Jacques and William Smith, neither of whom were present, were read by others.

"On Wednesday evening the British Chapter of the American Academy gave an informal cocktail party at the Naval and Military Club, 42 Half Moon Street, London for overseas visitors. This was a delightful affair and our English chapter are to be complimented on their splendid hospitality.

"On Thursday evening at the formal banquet I was called upon as the representative of the U. S. to speak on behalf of all the overseas visitors. On Friday evening we were the guests of the Minister of Health, the Right Honorable Hilary Marquand, at a reception and cocktail party at Lancaster House. After this affair, ten of us overseas visitors were the guests of Lord Charnwood at the St. James Club for dinner.

"All in all, we here in America would be hard put to equal the hospitality shown us by our British colleagues. The educational sessions were prompt and dignified and the papers of unusually high caliber.

"The Congress and the Exposition brought together a large group of refractionists from all over the world and presented a never to be forgotten opportunity to discuss our mutual problems."

Dr. Neill further reports that as a result of his trip, he has recommended to the American Optometric Association their reaffiliation with the International Optical League, which held meetings concurrently with the Congress and Exposition, and which sponsors programs to further professional advancement on a world-wide front. The A. O. A. was at one time a member of the League.

Dr. E. Fisher, Dean of the College of Optometry, Ontario, Canada, also presented a paper at the Congress on "Accommodation-Convergence Relationships." American papers mentioned by Dr. Neill that were read in the absence of the authors were, "Visual Skills Training," by Dr. Louis Jacques, of Hollywood, California, and "Orthoptics From the Standpoint of Clinical Procedure," by Dr. William Smith, Boston, Massachusetts. Martin Topaz, Editor of *The Optometric Weekly*, also attended the Congress.

Special tribute was paid during the educational sessions to Hermann von Helmholtz in light of the 100th anniversary of his epoch-making book *Beschreibung eines Augenspiegels* published in 1851, and exhibited at King's College during the Congress (a first edition owned by the British Optical Association).

Congress sidelight: Many Americans who have had the pleasure of meeting Britain's Lord Charnwood have heard him speak fondly of his 1904 Lanchester. The Congress gave him an opportunity to show the delegates the real thing, and some enjoyed a turn around the block with Lord Charnwood at the wheel. The July weather was perfect for the open air ride, even though occupants hadn't thought to bring dusters and goggles along.

Other hosts to visitors during the Congress in addition to the British Optical Association, were the Association of Optical Practitioners, the Worshipful Company of Spectacle Makers, and the Scottish Association of Opticians. The latter entertained Dr. Neill and others with a dinner, tour of Stow College for optometric training and a sightseeing trip.

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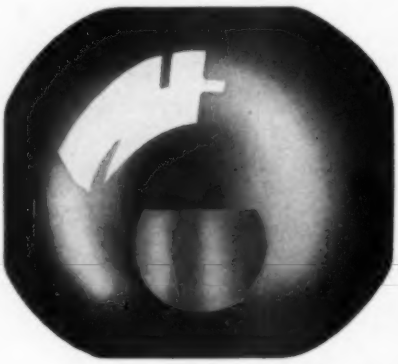

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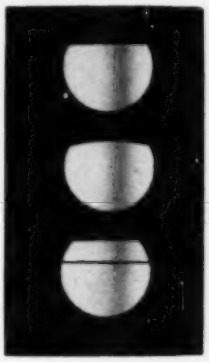

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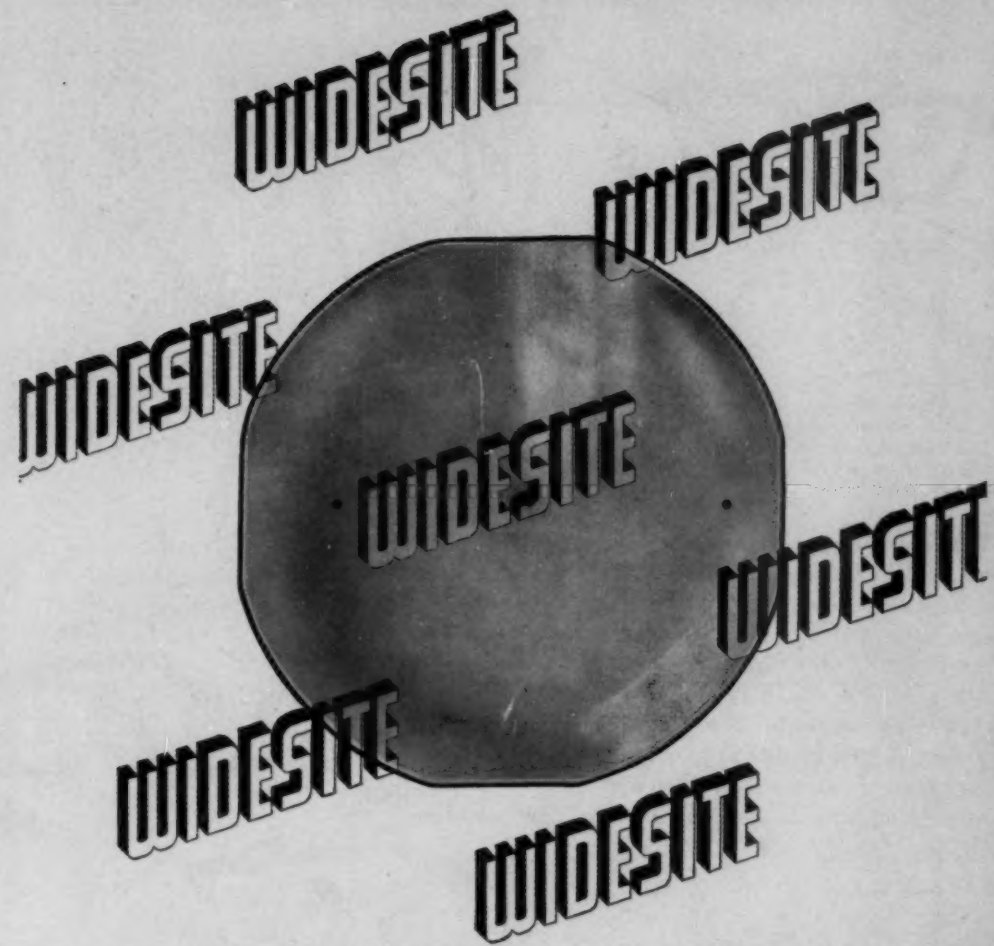

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